Tour-Based Microsimulation of Urban Commercial Movements

by

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Commercial Vehicle Movements

- Vehicles operated for commercial purposes
- As opposed to household, personal movements
- Includes ‘non-commercial’ non-household purposes (government, not-for-profit)
- Comprise 10-15% of total urban traffic

Some Examples

Commercial

- Hauling freight for a company
- Service workers visiting clients
- Sales meetings
- Mail
- Delivering parcels

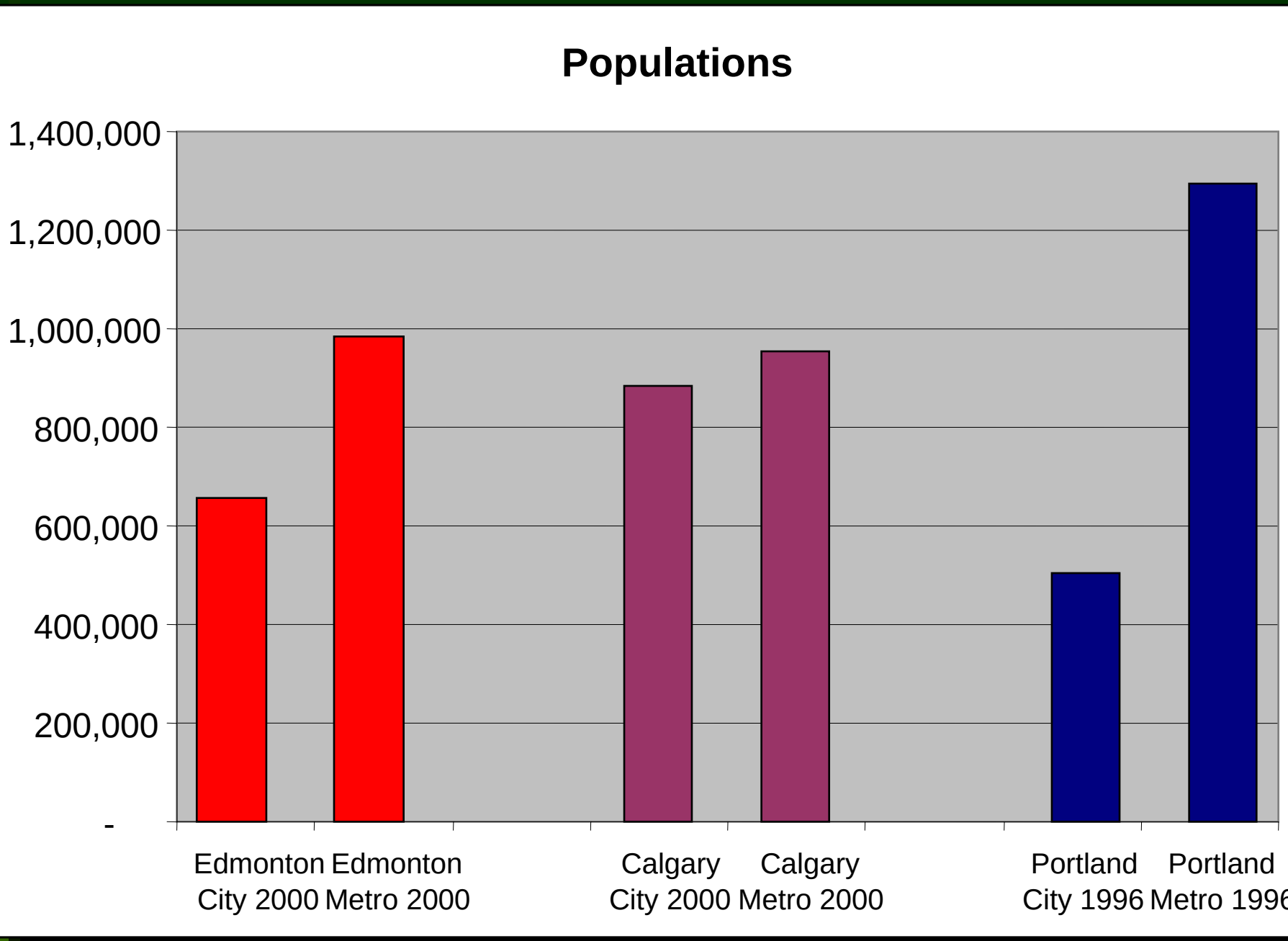
Personal

- Travel to work
- Travel to school
- Shopping
- Leisure trips
- Social visits

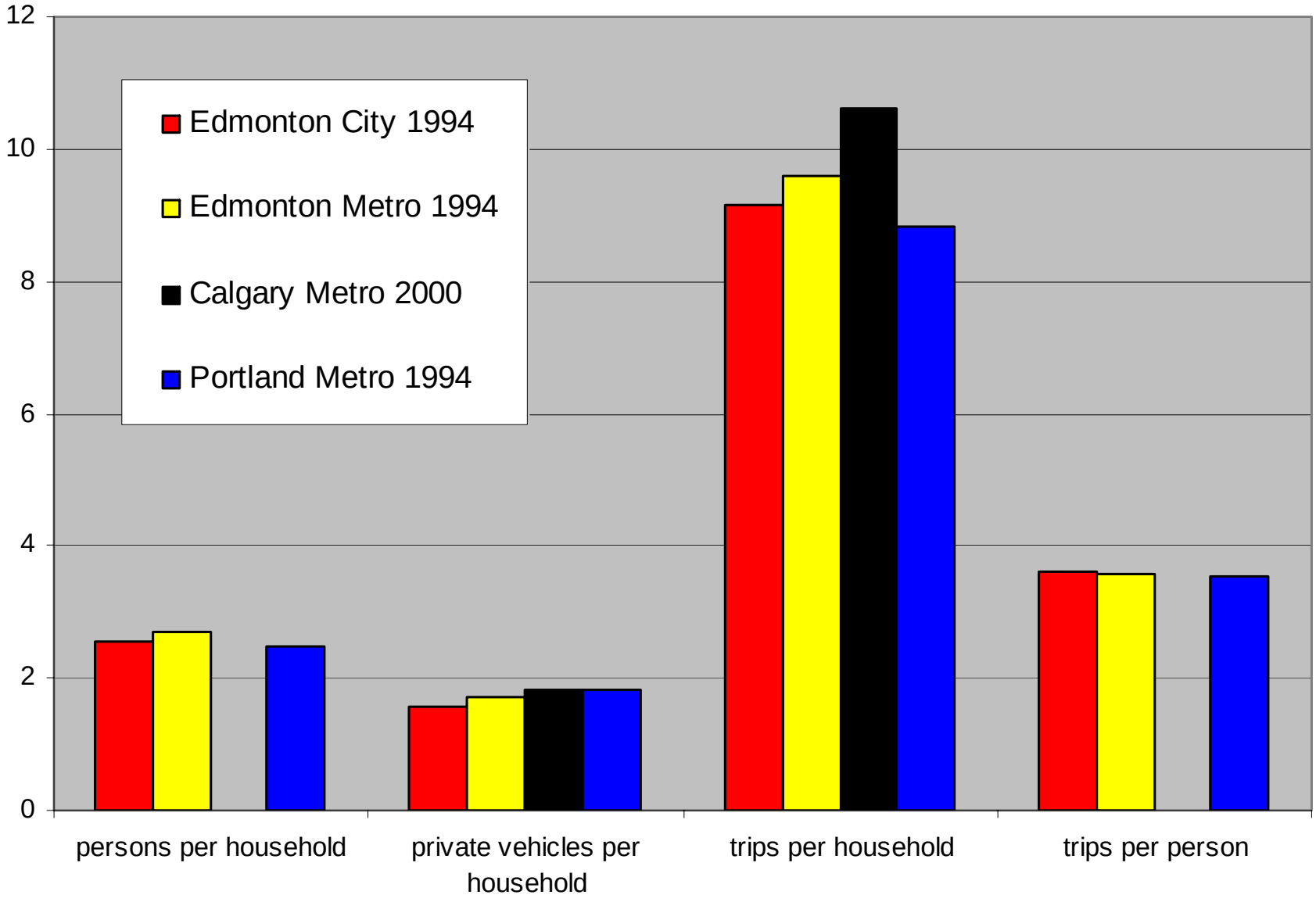
Modelling Requirements

- Policy Sensitive
  - Truck Routes
  - Operating Costs and Related Taxes
  - Land Use Zoning
- Accurate
  - Responsiveness
  - Fidelity
- Practical
  - Reasonable data requirements for running
- Fit with current household travel model

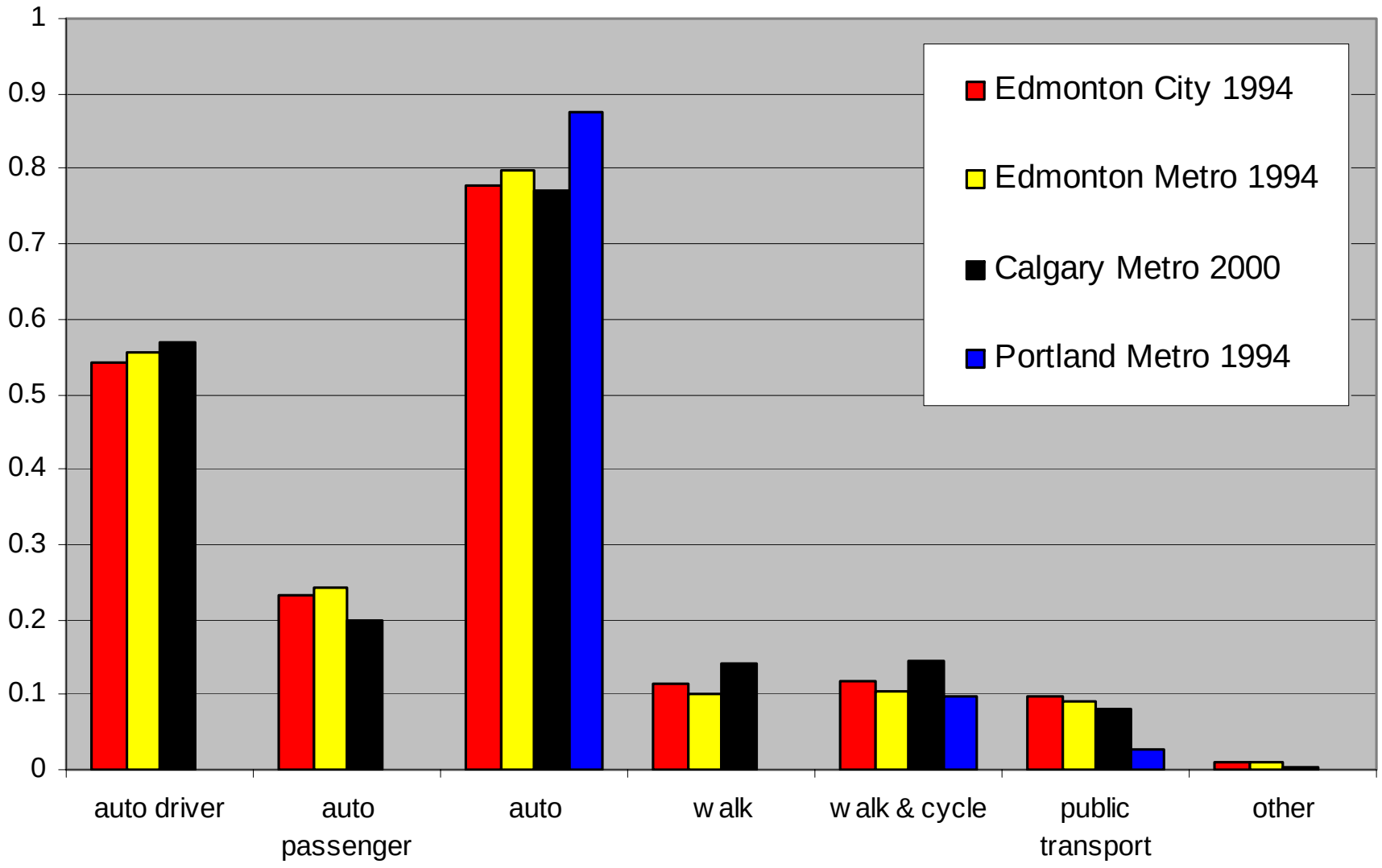
Base 802660AI (R01930) 9-99


Populations
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
-
Edmonton City 2000
Edmonton Metro 2000
Calgary City 2000
Calgary Metro 2000
Portland City 1996
Portland Metro 1996

Trip Making

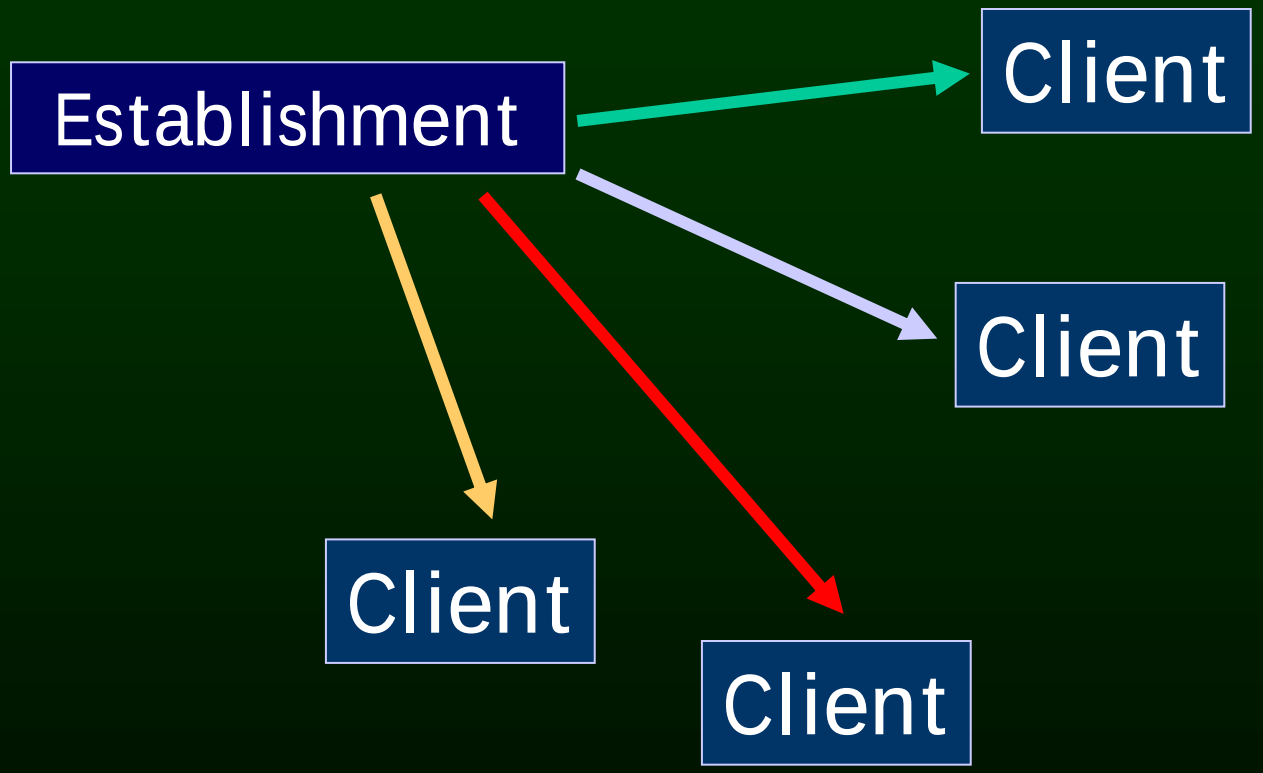

12
10
8
6
4
2
0
Edmonton City 1994
Edmonton Metro 1994
Calgary Metro 2000
Portland Metro 1994
persons per household
private vehicles per household
trips per household
trips per person

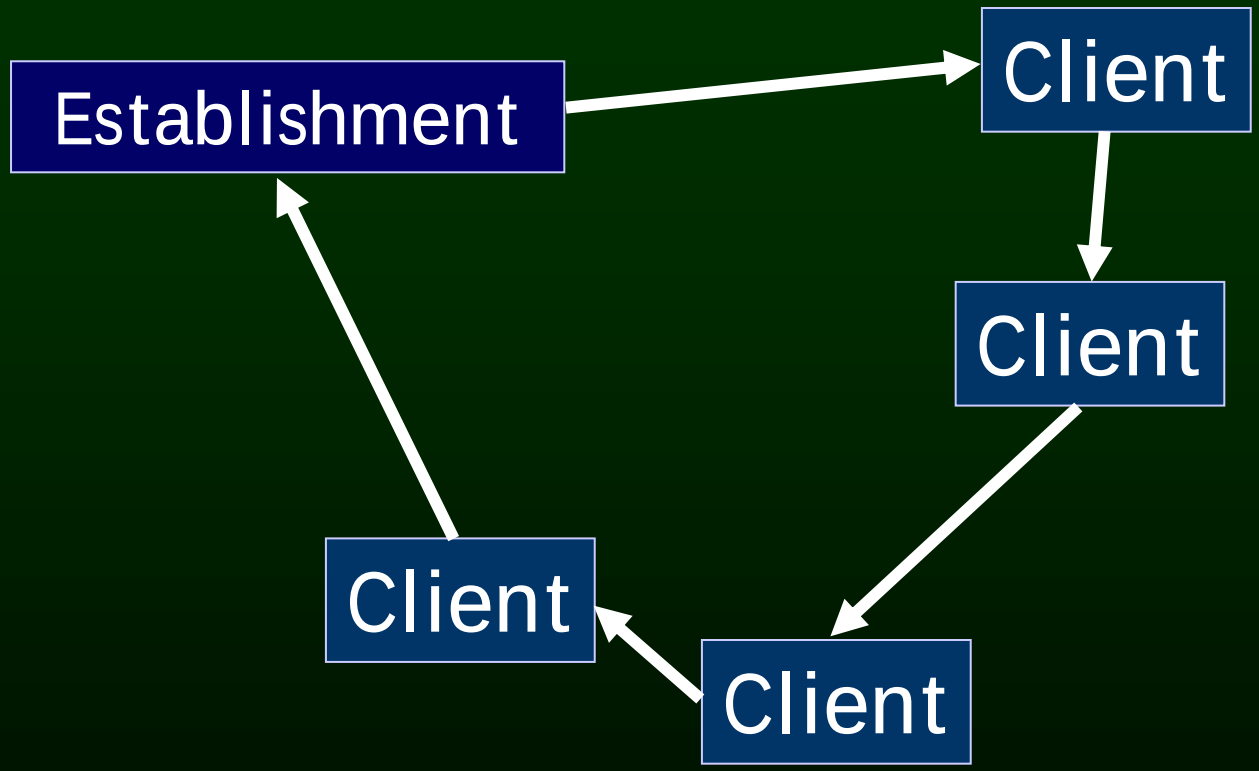
Weekday Trip Mode Split



Tour-based Microsimulation

- Consider tours rather than individual trips
- Microsimulation of each tour
  - Monte Carlo techniques
  - Disaggregate choice-based sampling distributions for decisions
- Uses additional information for decisions
  - Full-tour conditions
  - Location of establishment (tour-base)
  - Workshift influences
  - Simulates each trip as tour progresses
- Closer to reality
  - A number of clients scattered throughout city
  - Efficient businesses will service them in tours
- Large number of stops and no apparent hierarchy:
  - 'Growing' rather than 'Rubber-banding'


Establishment
Client
Client
Client
Client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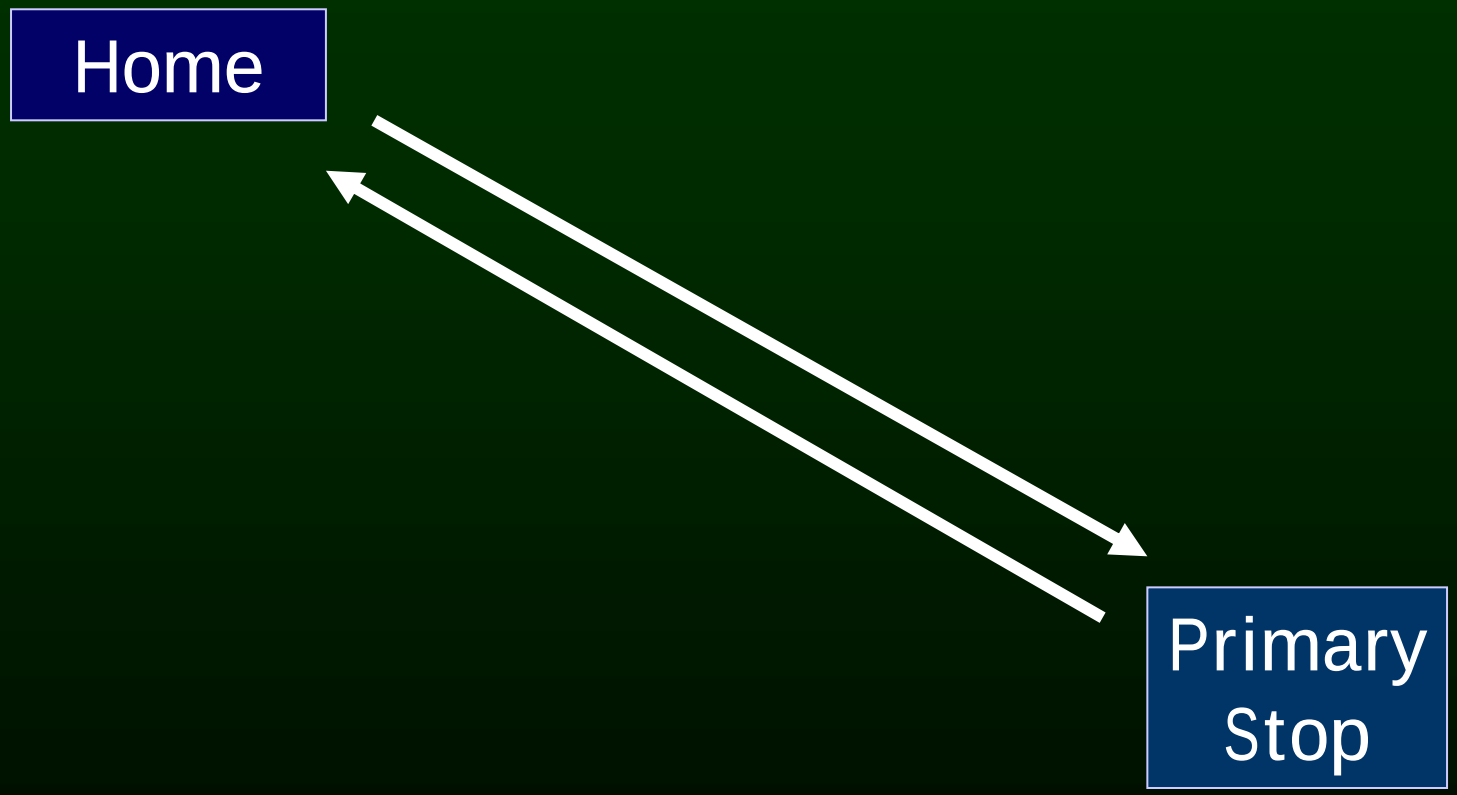
Rubberbanding Tours

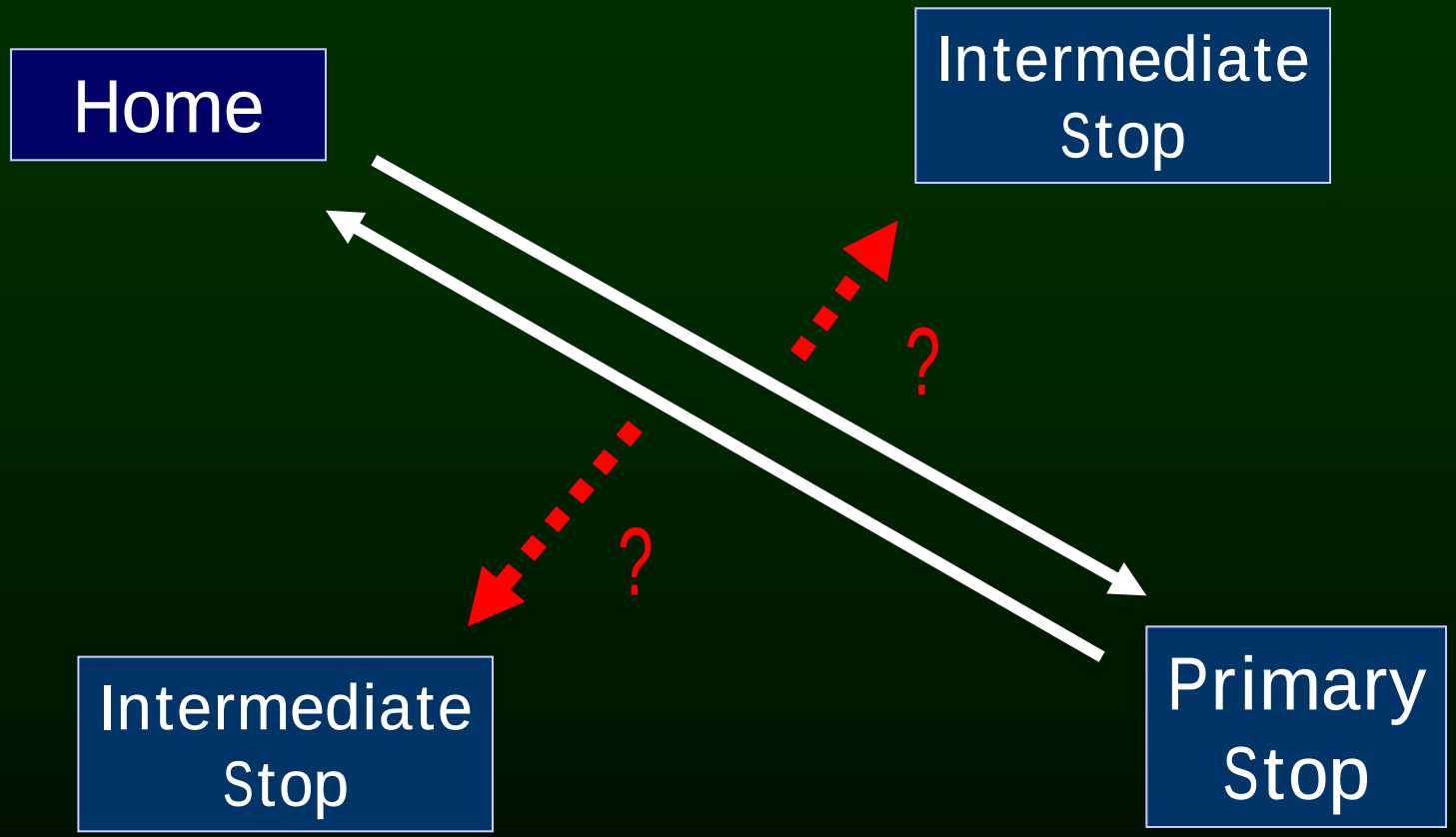
Home

Primary Stop

Rubberbanding Tours



Rubberbanding Tours



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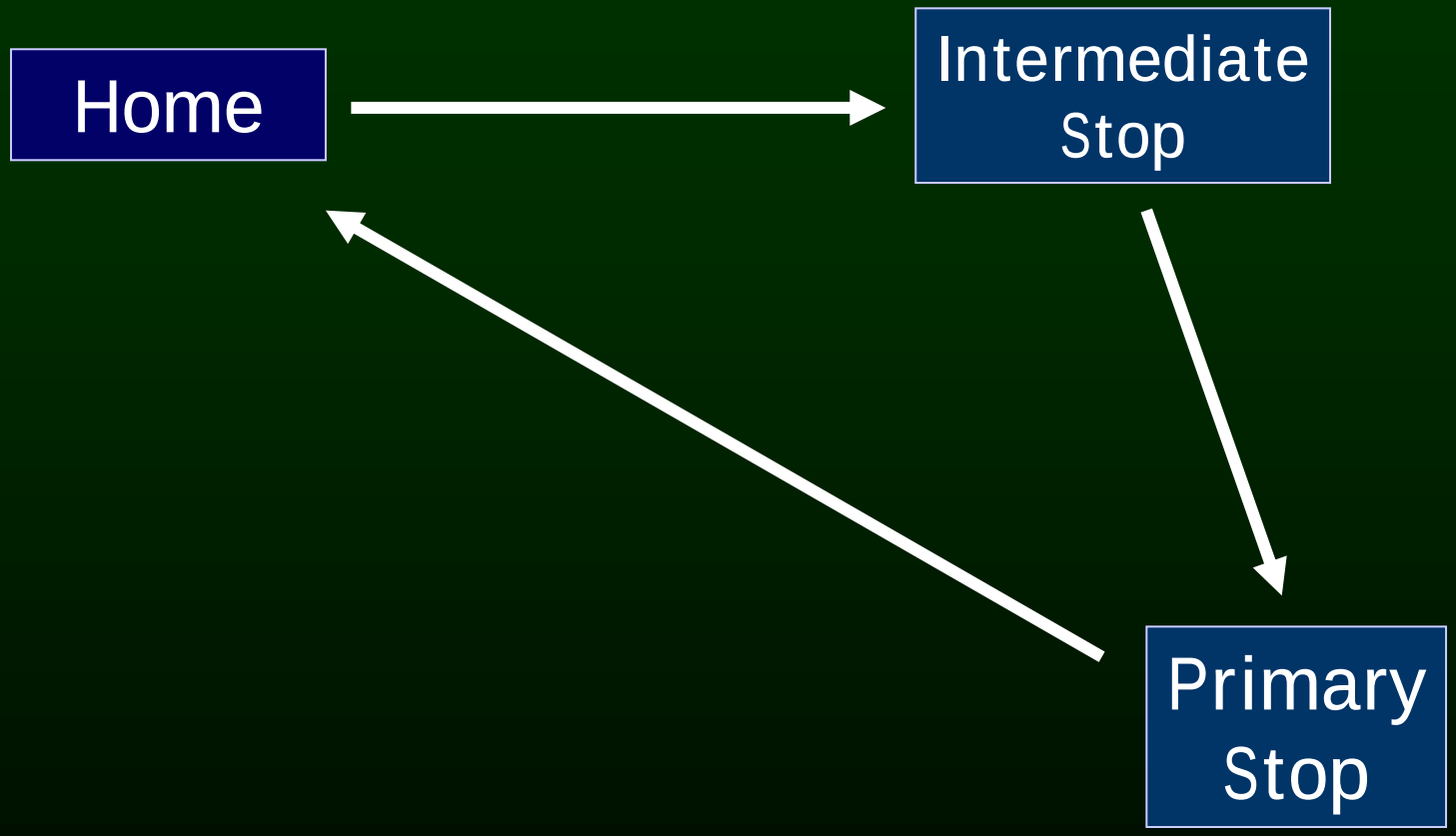

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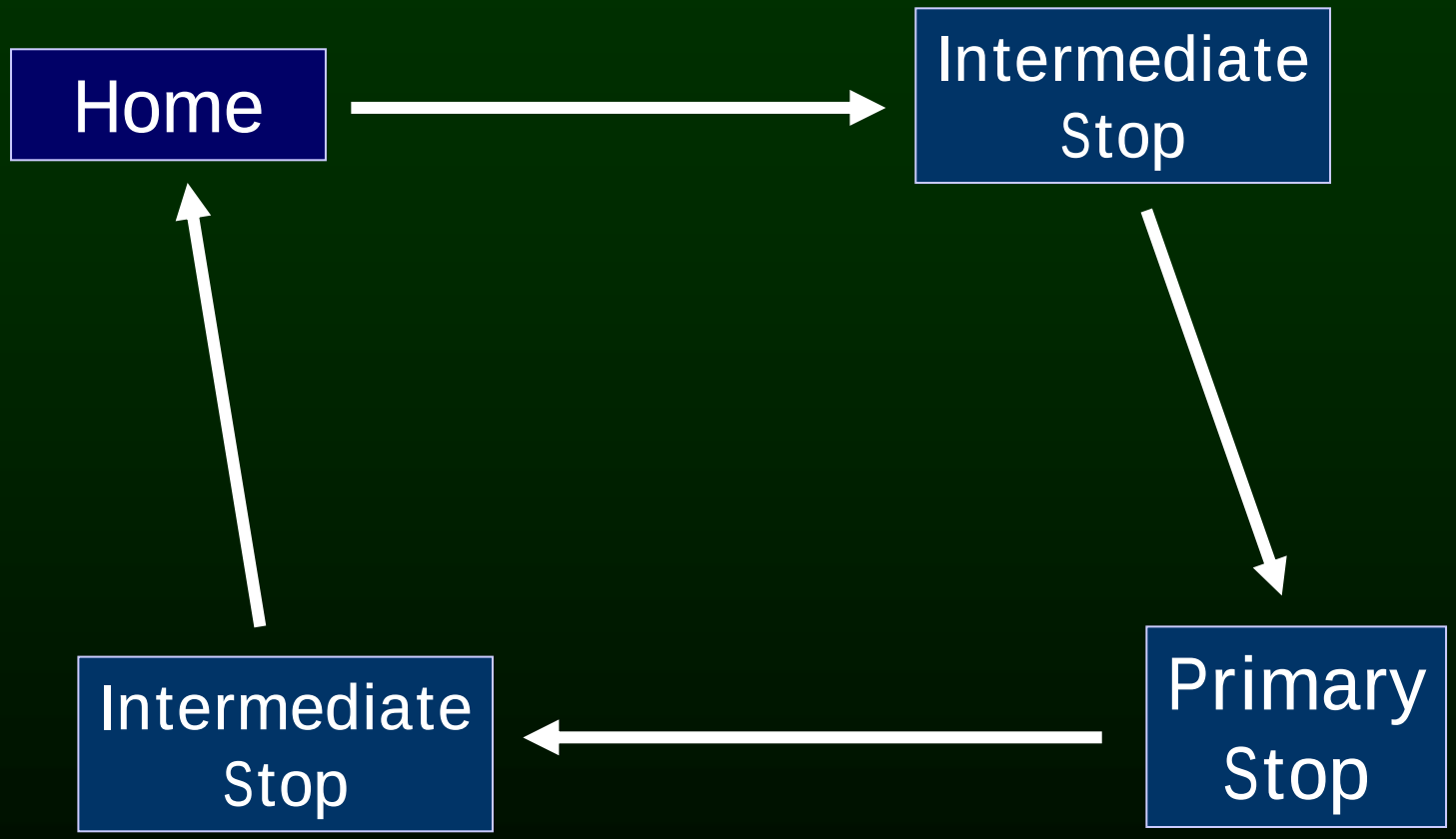
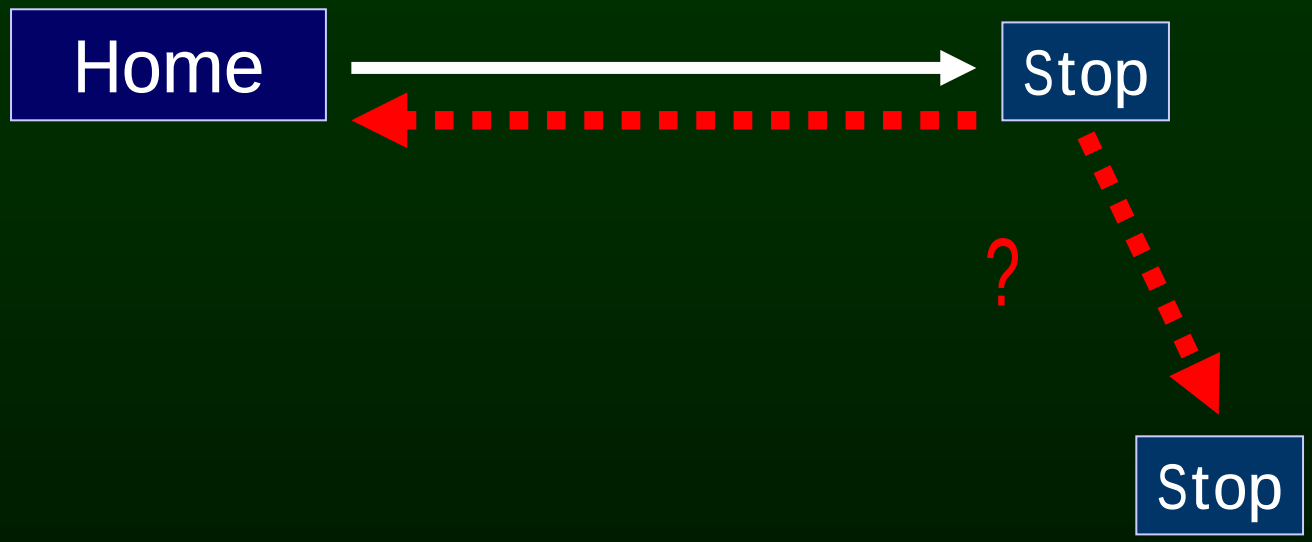
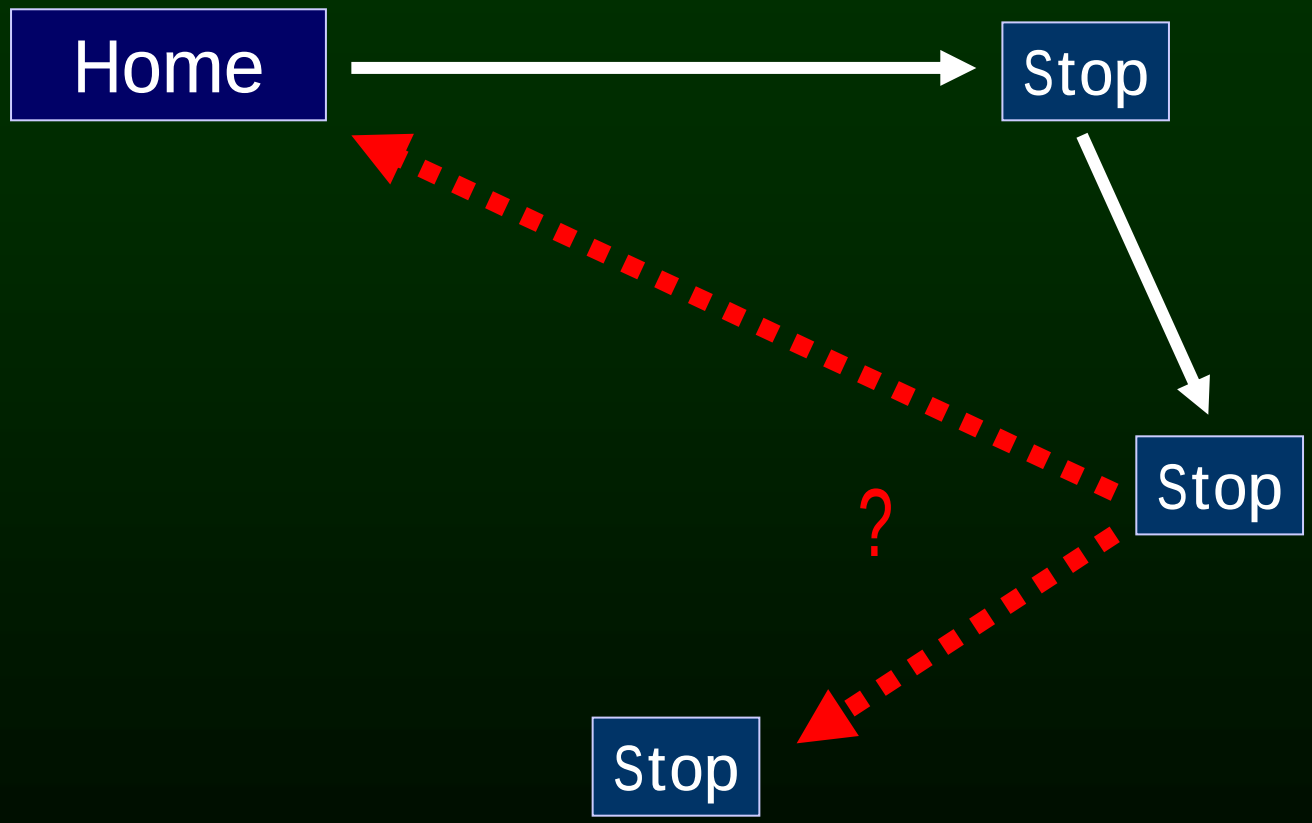


Growing Tours



Growing Tours

Growing Tours



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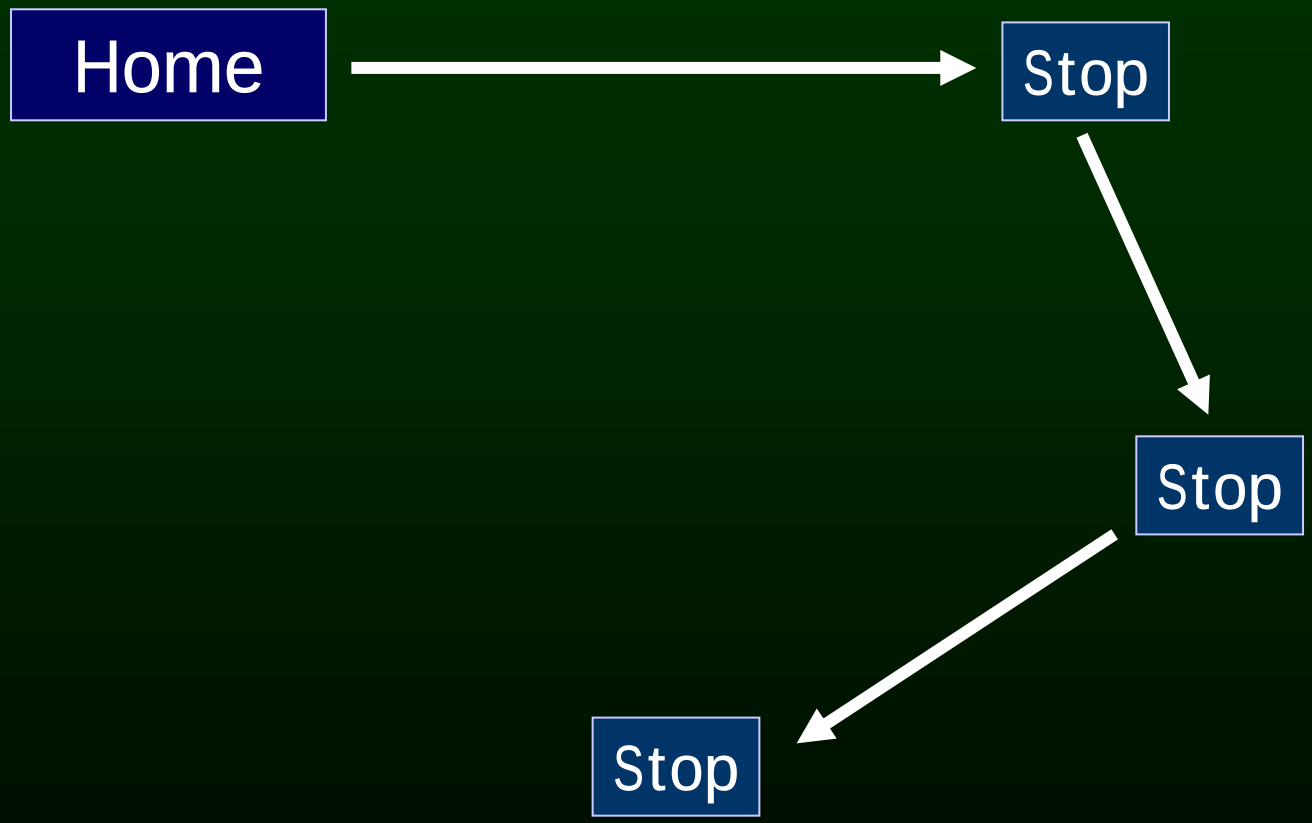

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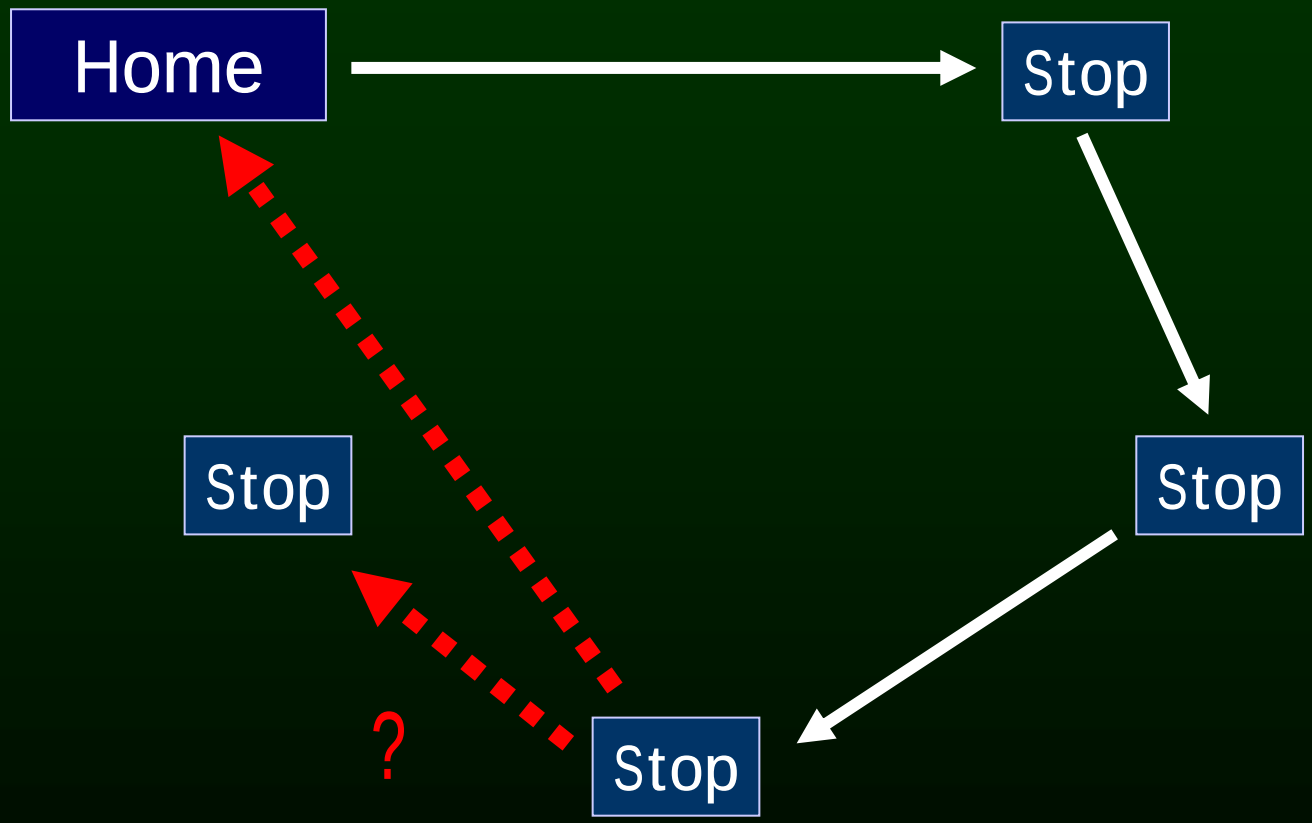

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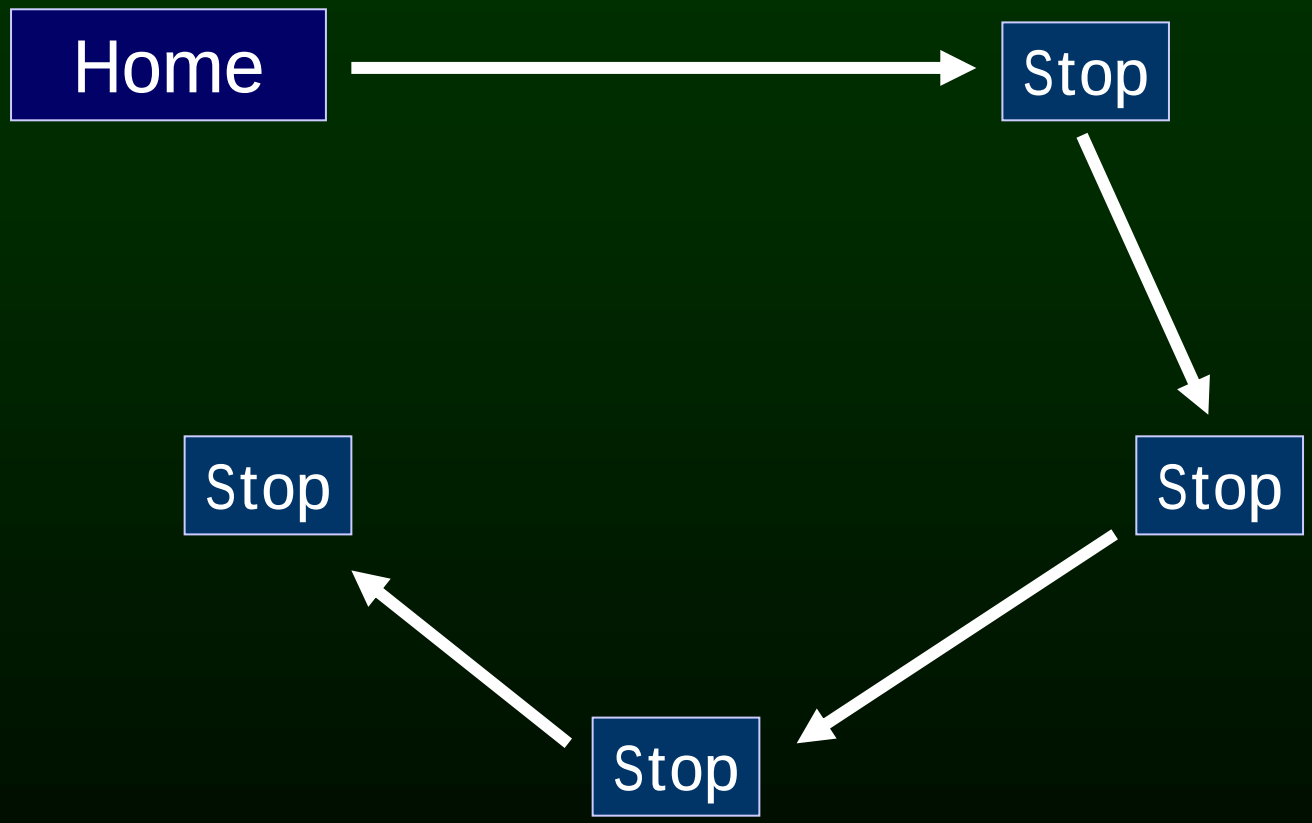

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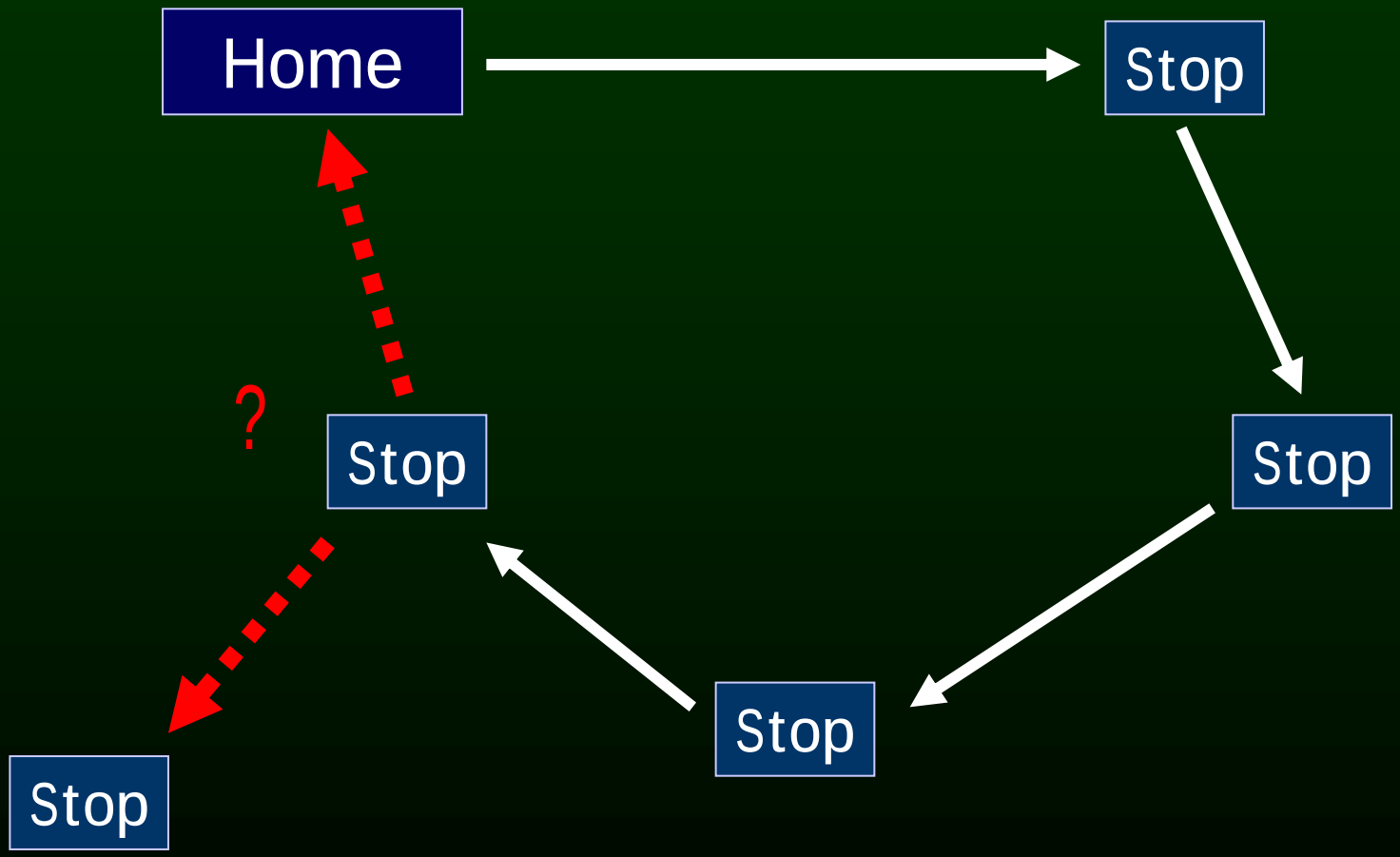

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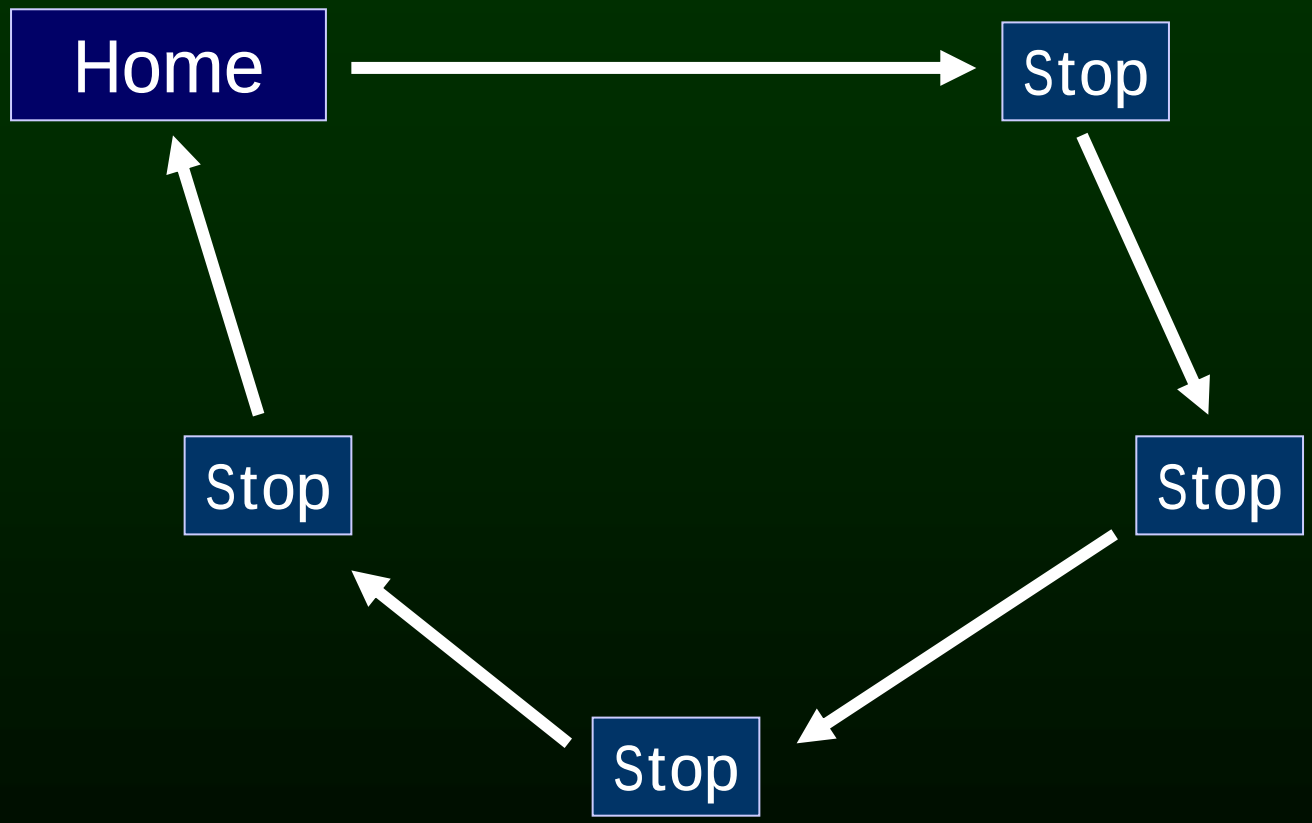
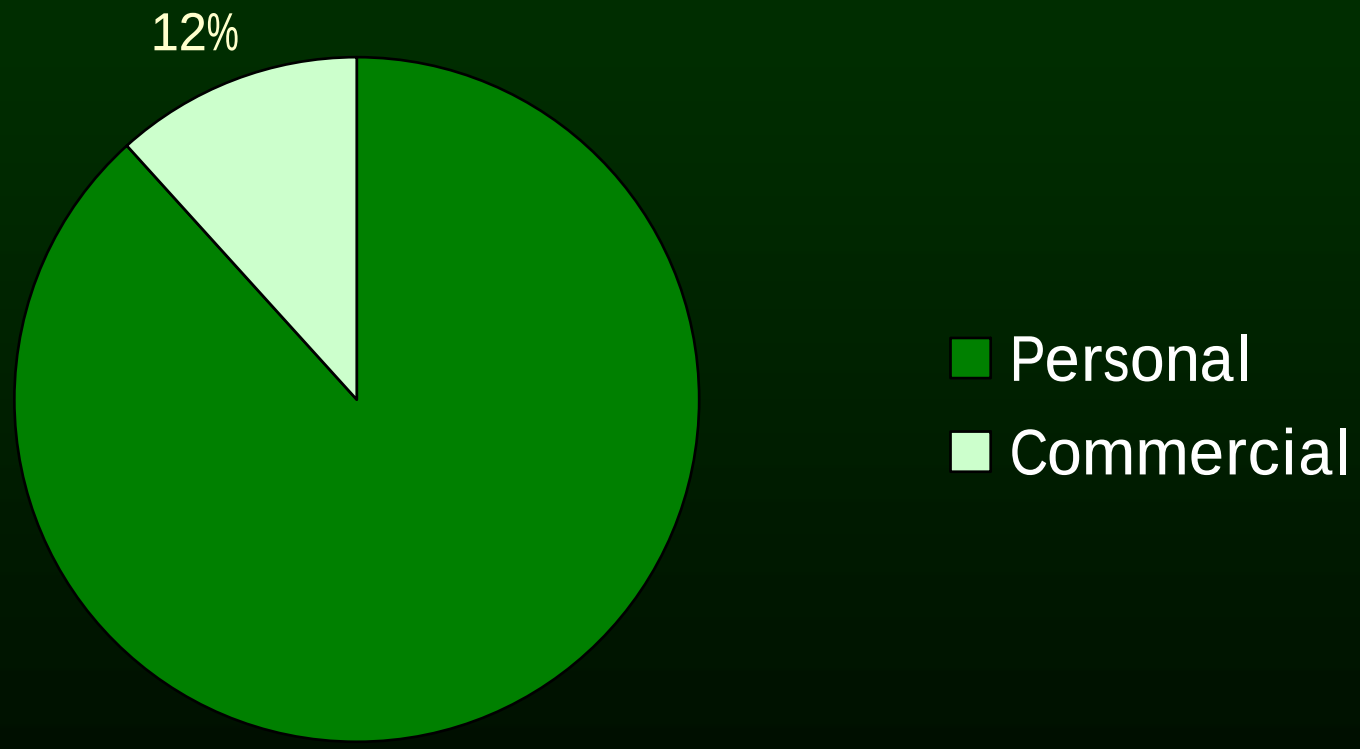


Data

- 2001 Commercial Movements Survey
- All commercial movements
  - Not just freight
  - Not just trucks
- 3,100 establishments in Calgary
- 4,300 establishments in Edmonton
- 24 hour stop diary
- Firmographics
  - Employment structure
  - Vehicle fleet

Some Aggregate Statistics

Urban Weekday Vehicle Trips



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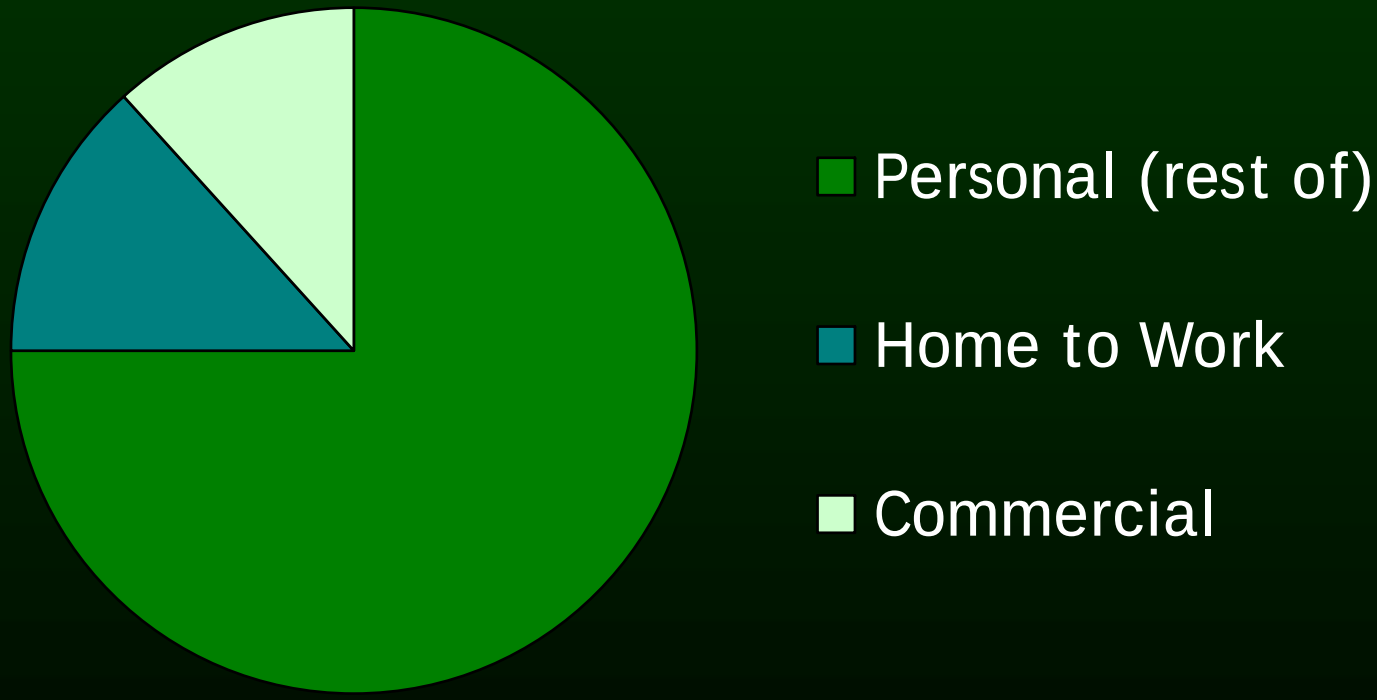
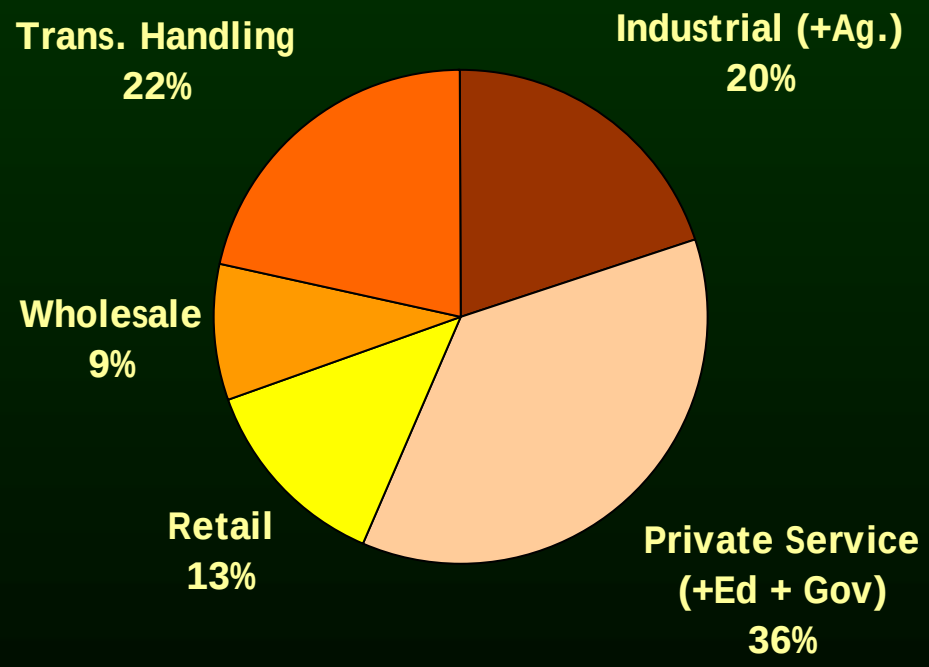


Industry Type

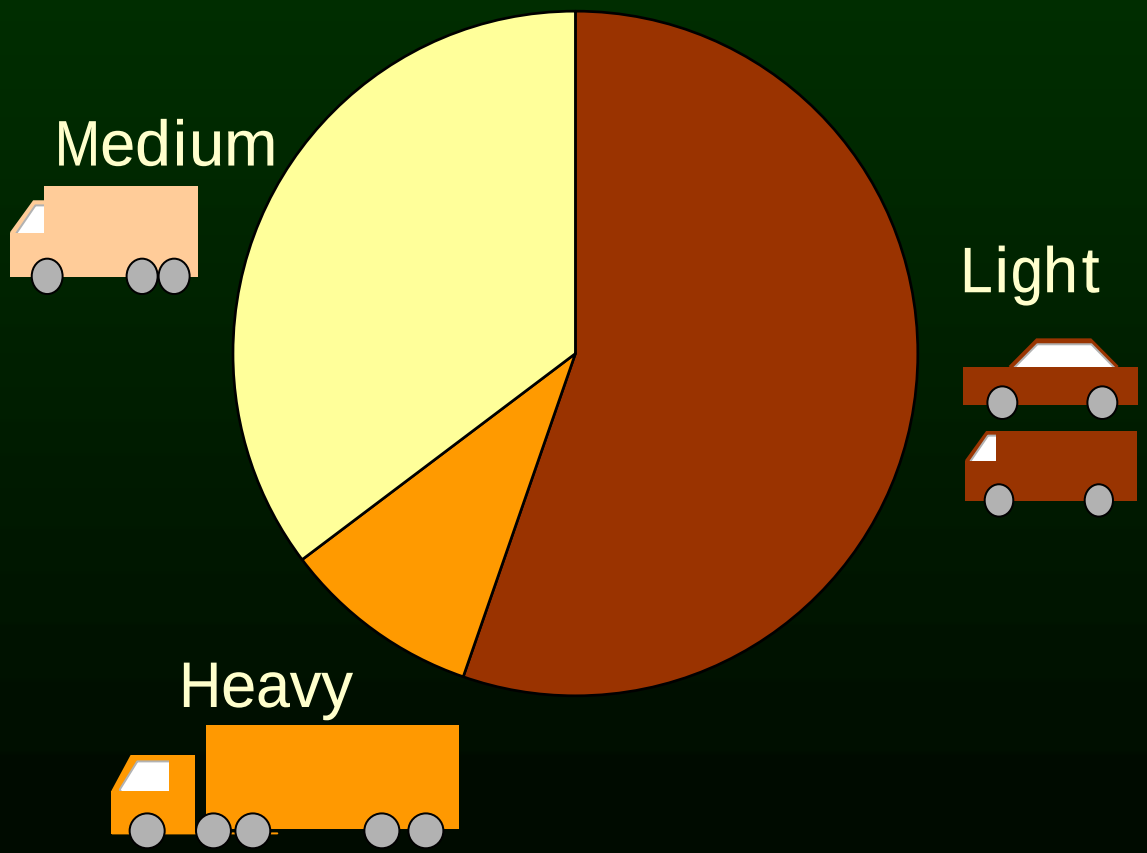
distribution of tours



Vehicle Type

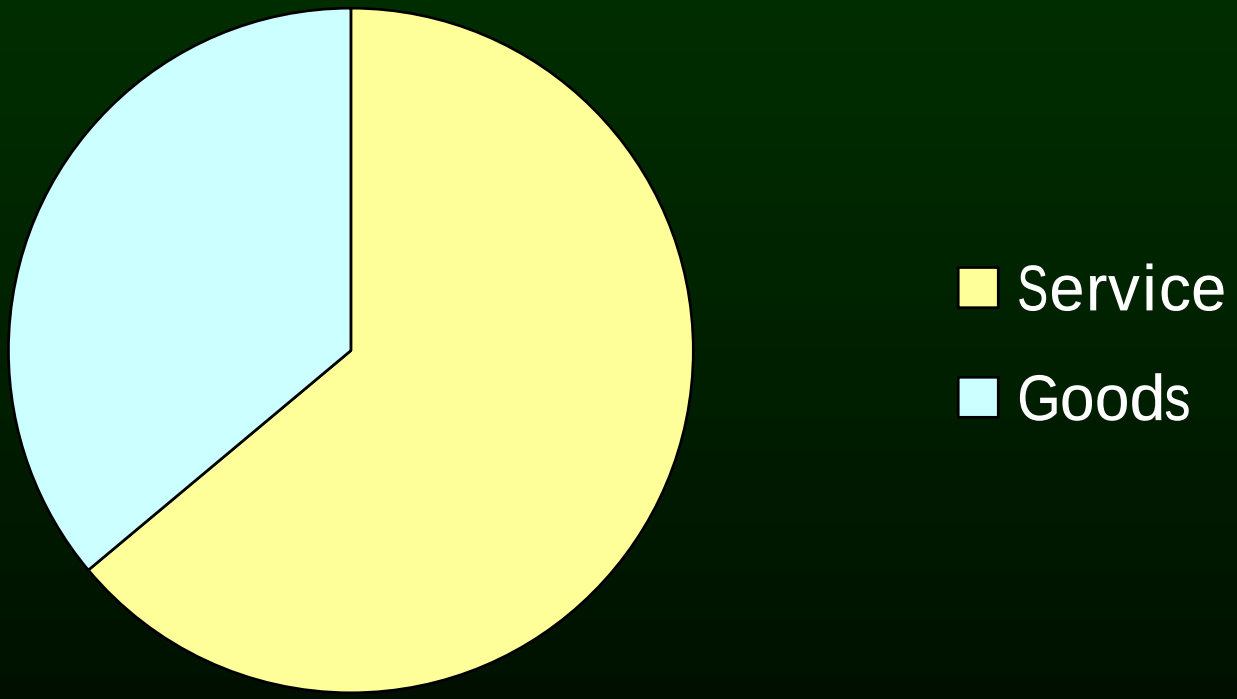
- Three vehicle types
  - Light (Autos, vans, pickup trucks - 4 wheels)
  - Medium (Single units - 6 wheels)
  - Heavy (Tractor trailer - >6 wheels)
- Provides differentiation
  - Different routes available (truck routes)
  - Different impacts on traffic demands and pavement loads
  - Different emissions rates

Commercial Fleet



Proportions of vehicle trips

Urban Commercial Stop Purposes



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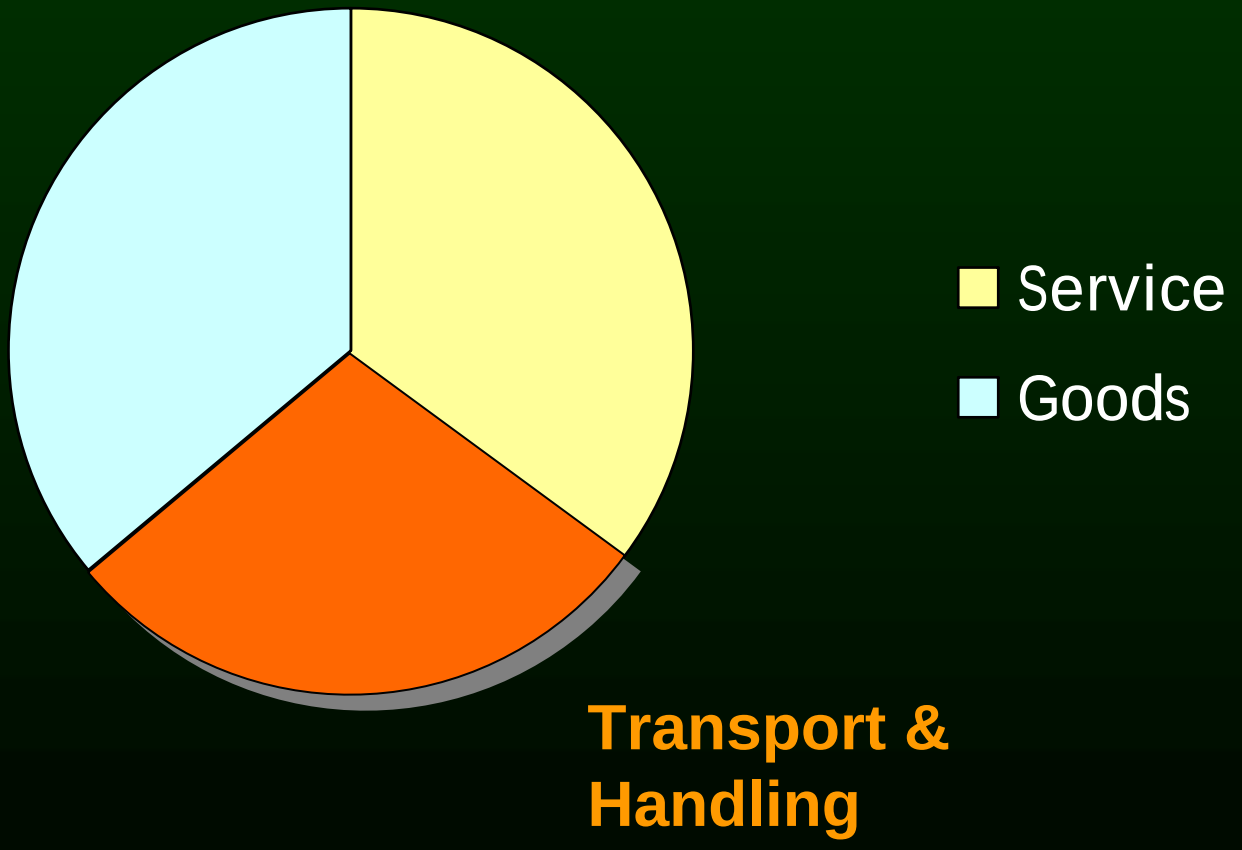
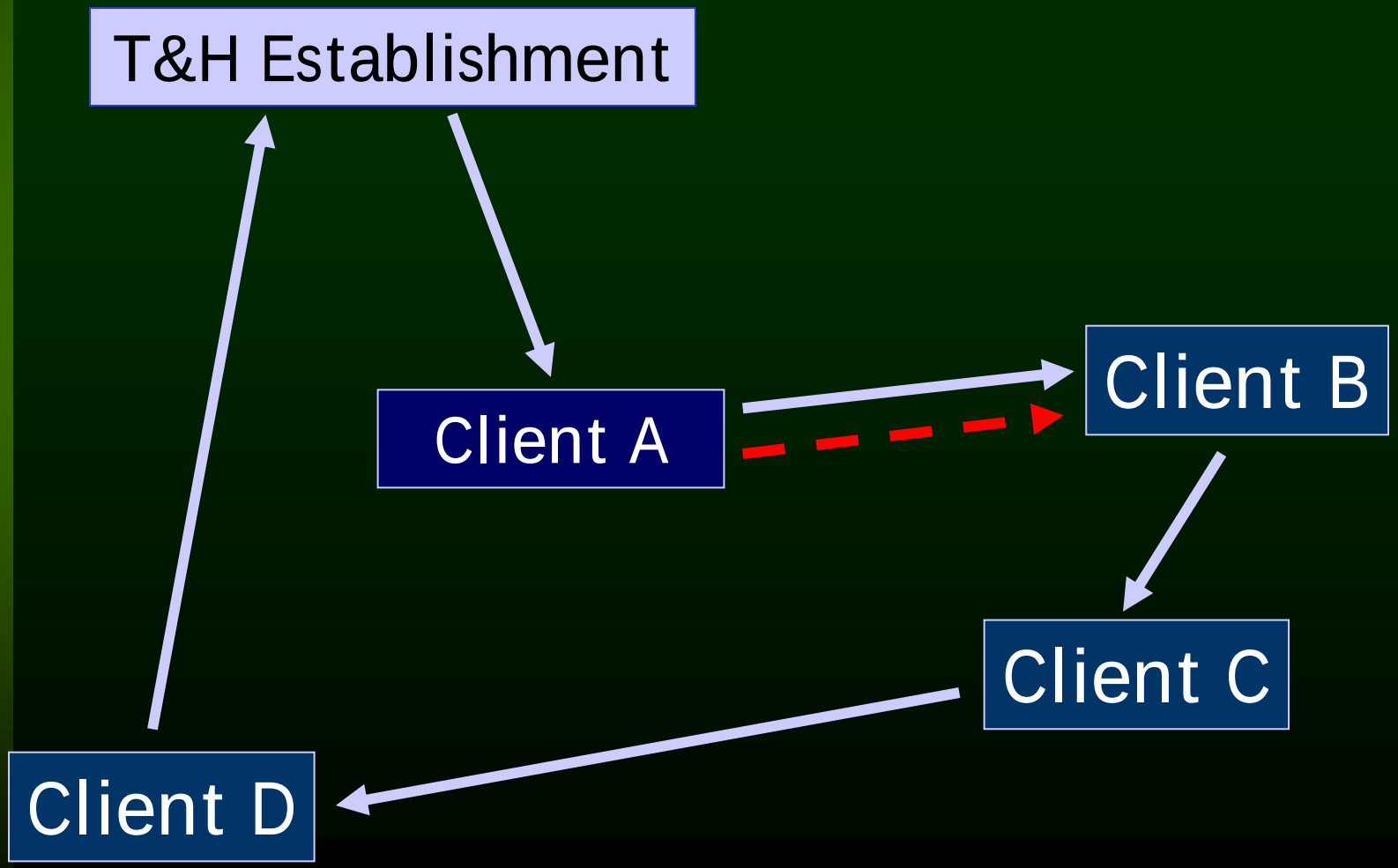


Transport & Handling



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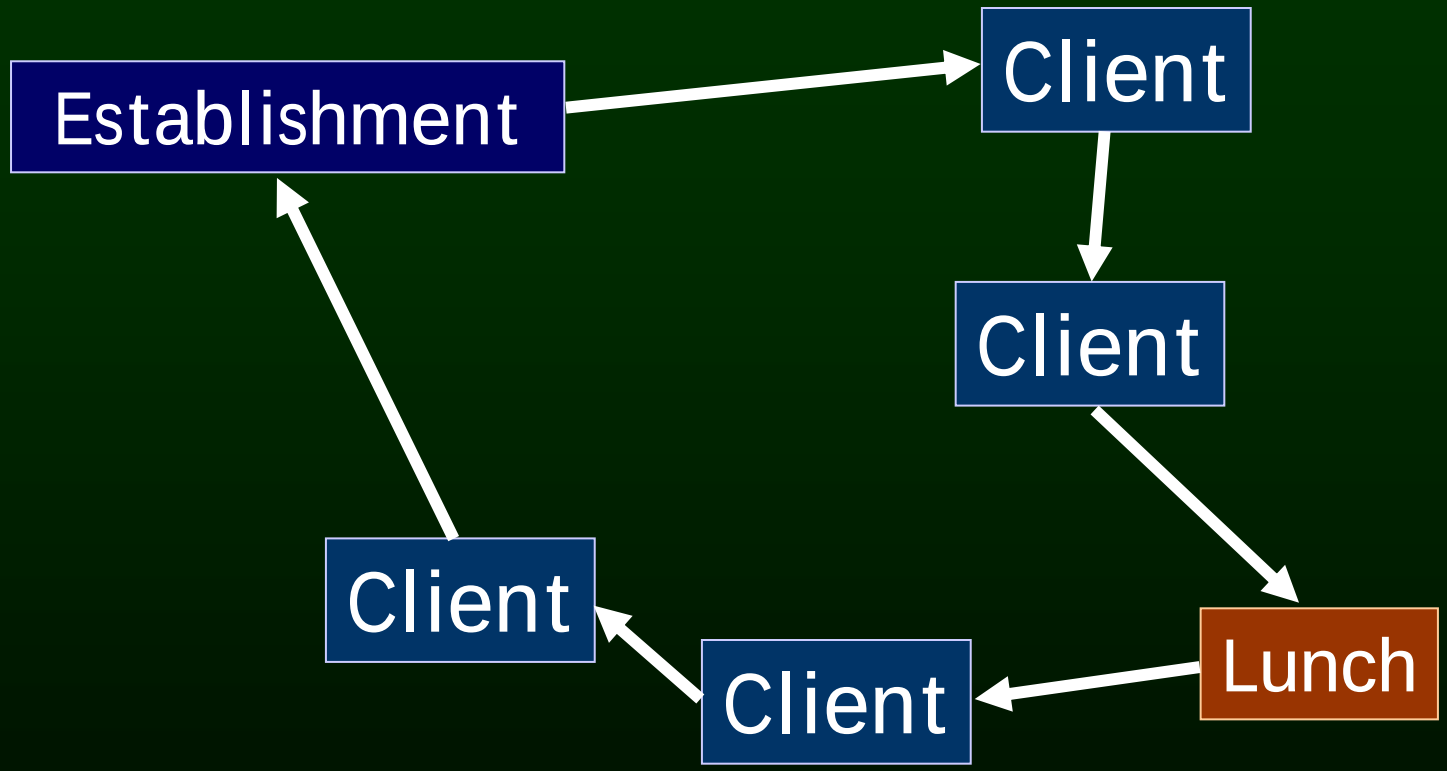
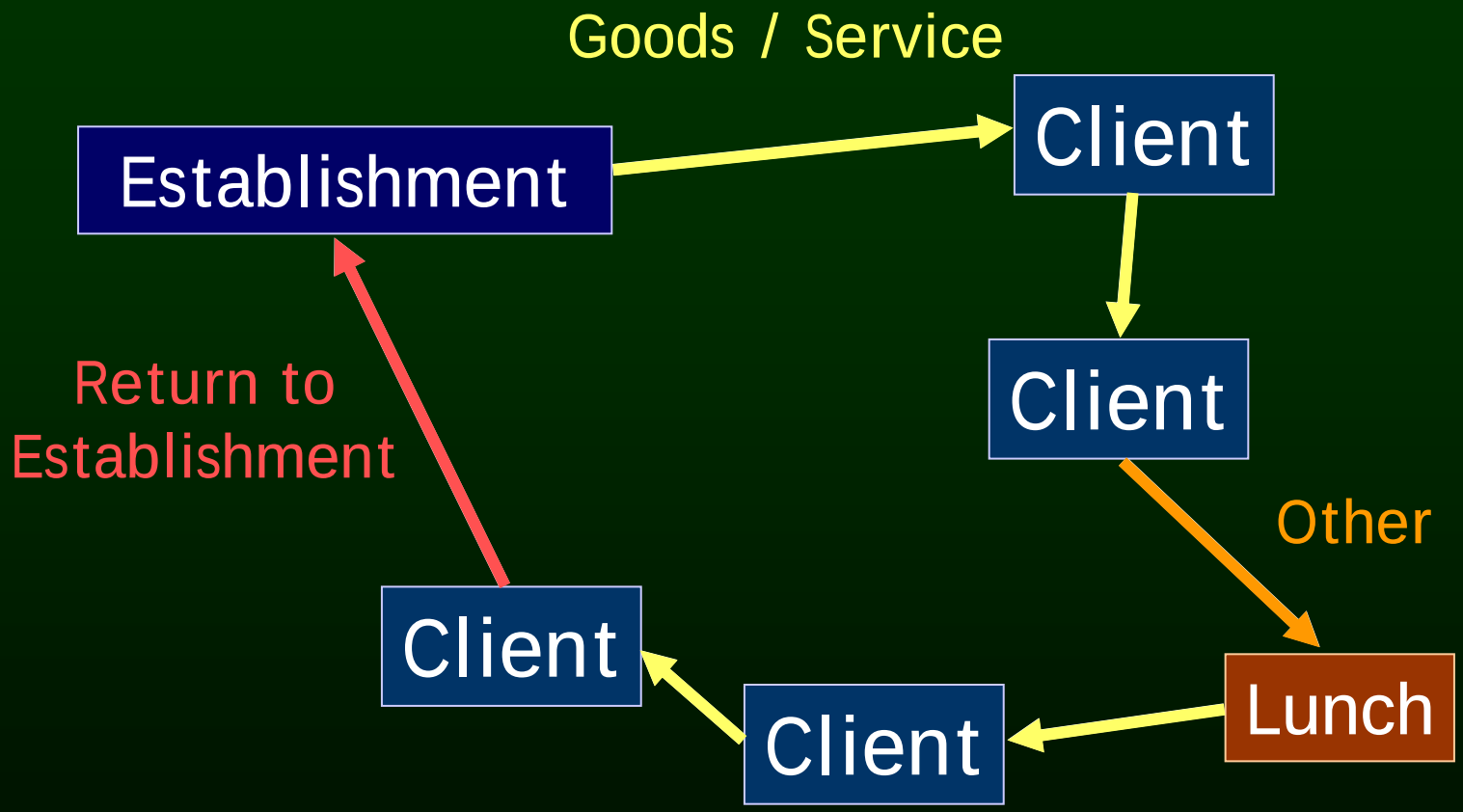



Goods / Service
Establishment
Client
Client
Other
Lunch
Client
Client
Return to Establishment

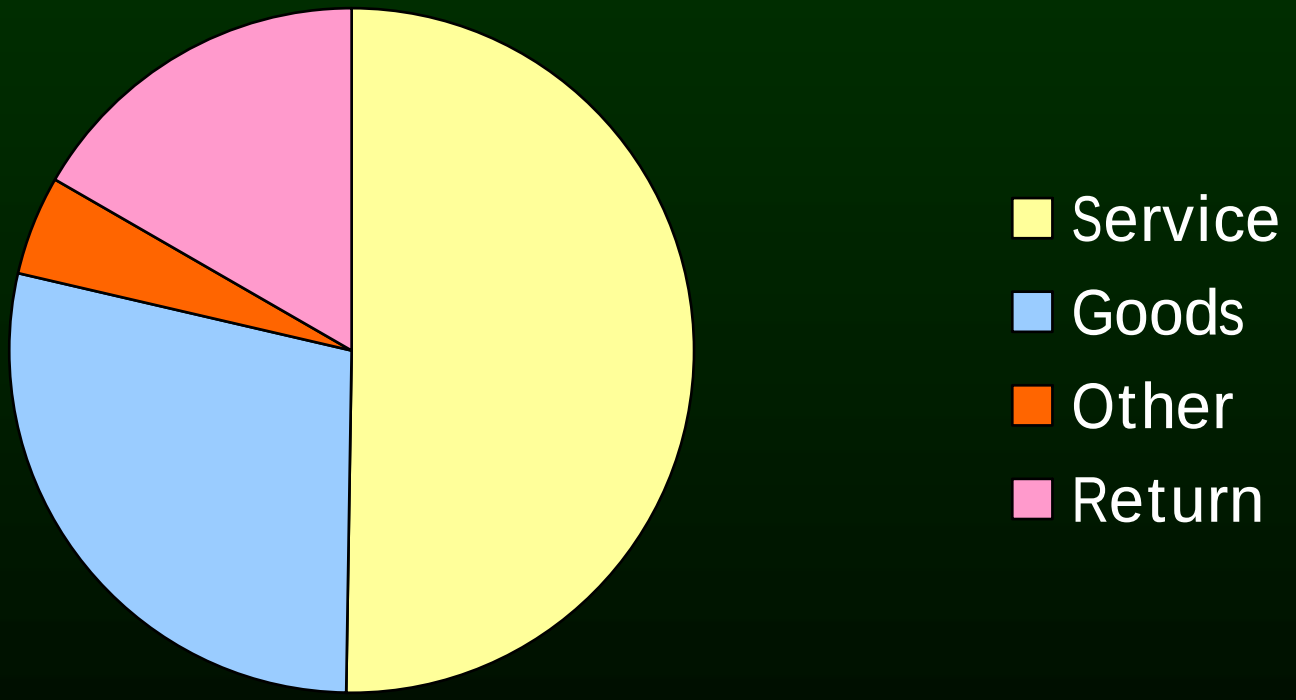
Stop Purposes

- Goods
  - Pick up goods
  - Drop off goods
  - Pick up and drop off goods
- Service
  - Perform service
  - Pick up supplies for performing service

Stop Purposes

- Other
  - Vehicle repair or fueling
  - Driver's personal stop (e.g. meal, snack, coffee, toilet, personal business)
  - Stop for indirect business purpose (e.g. bank)
- Return
  - Return to establishment
  - Last stop of a tour

Stop Purposes

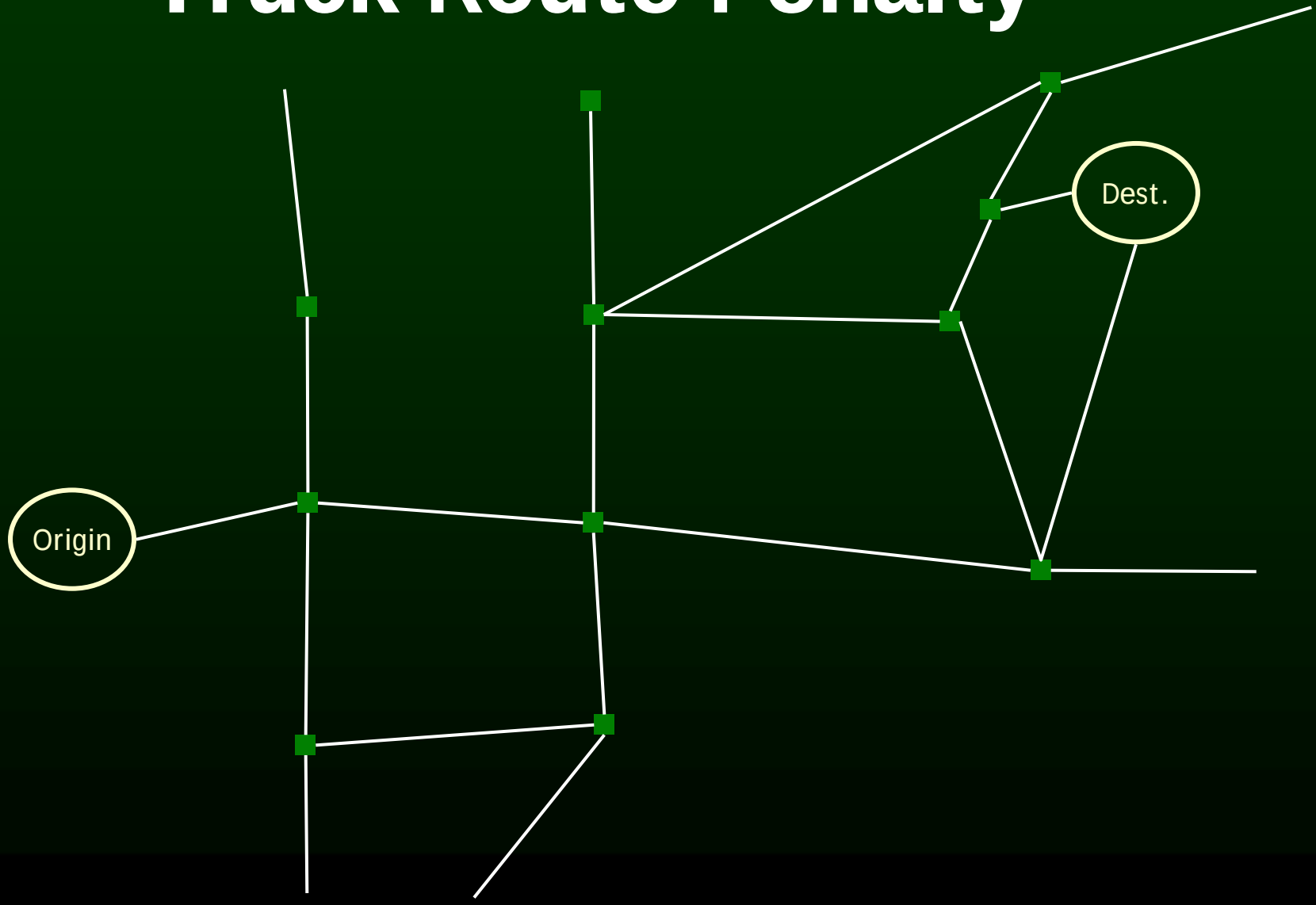


Modelling

Truck Path Choice

- Commercial vehicles assigned to road network
  - Generalized cost including time and distance
  - Identify routes used between zones
- Truck Route policy
  - OK to use designated truck roads
  - Minimize distance on non-truck roads
- Developed Truck Route path choice algorithm
  - Add 100 minute penalty for each 50m length on non-truck roads, rounded up to nearest whole number
  - Use cost with penalty for path choice
  - Remove whole numbers of 100s of minutes using modulus operator for determination of path costs

Truck Route Penalty



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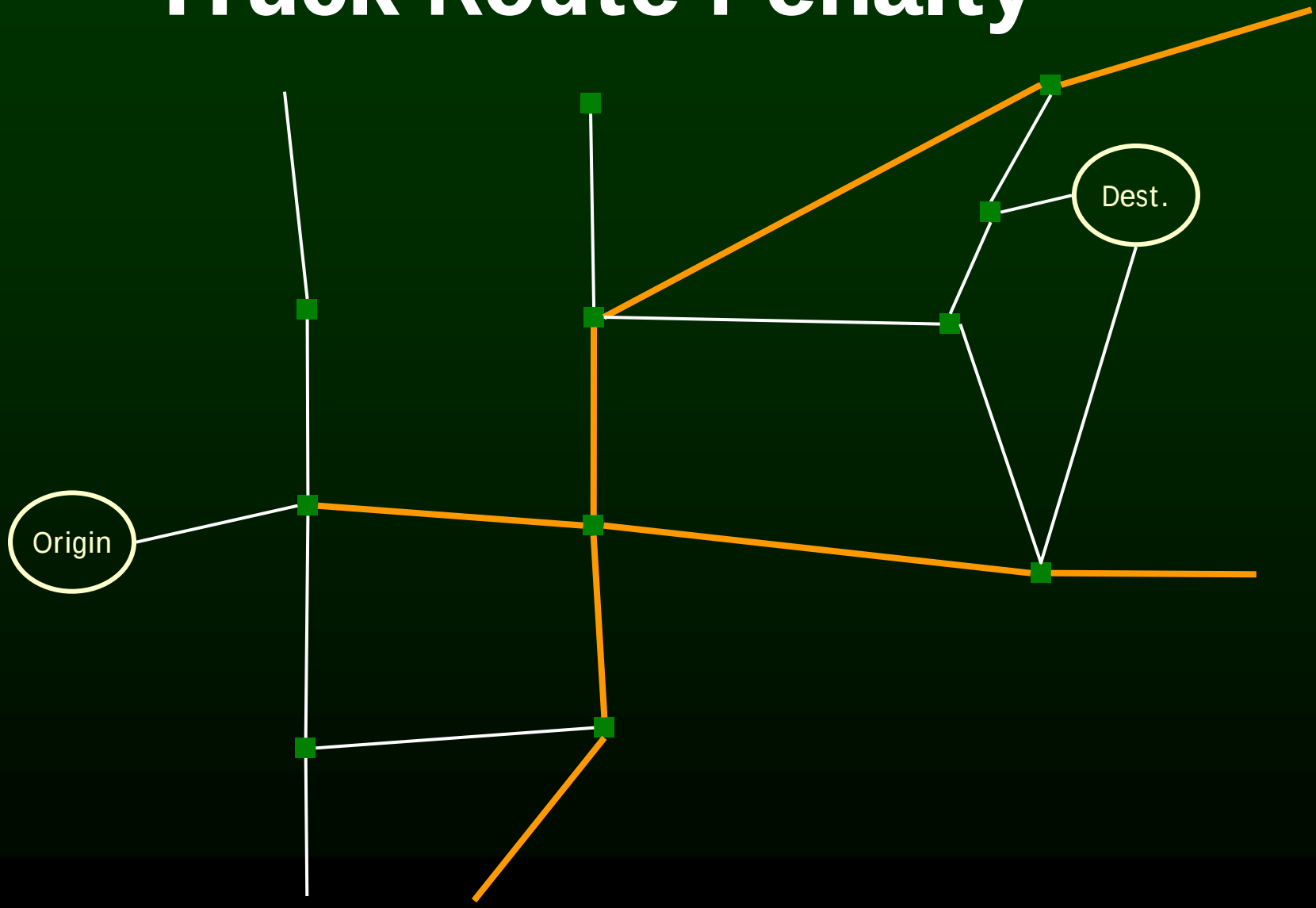

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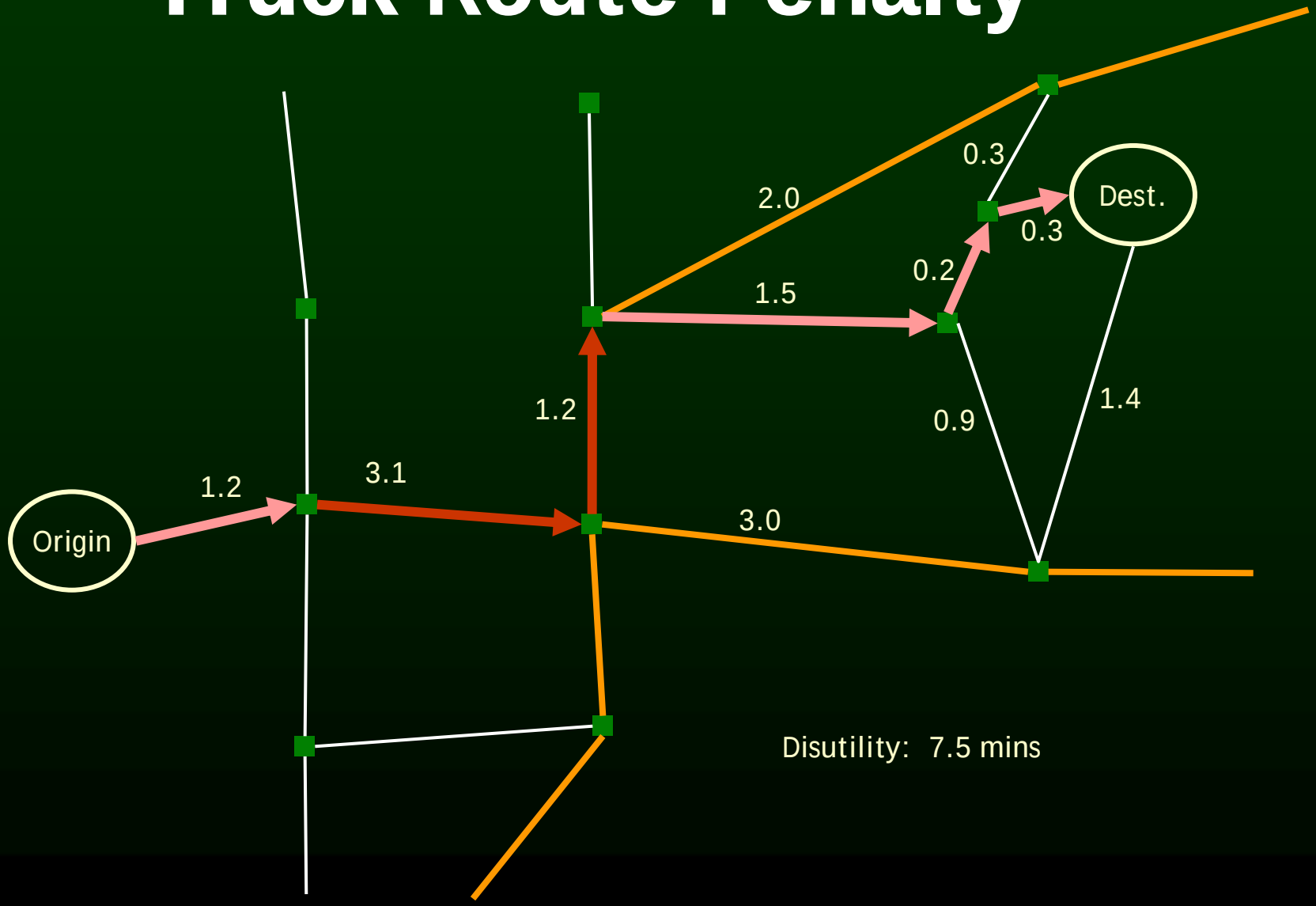

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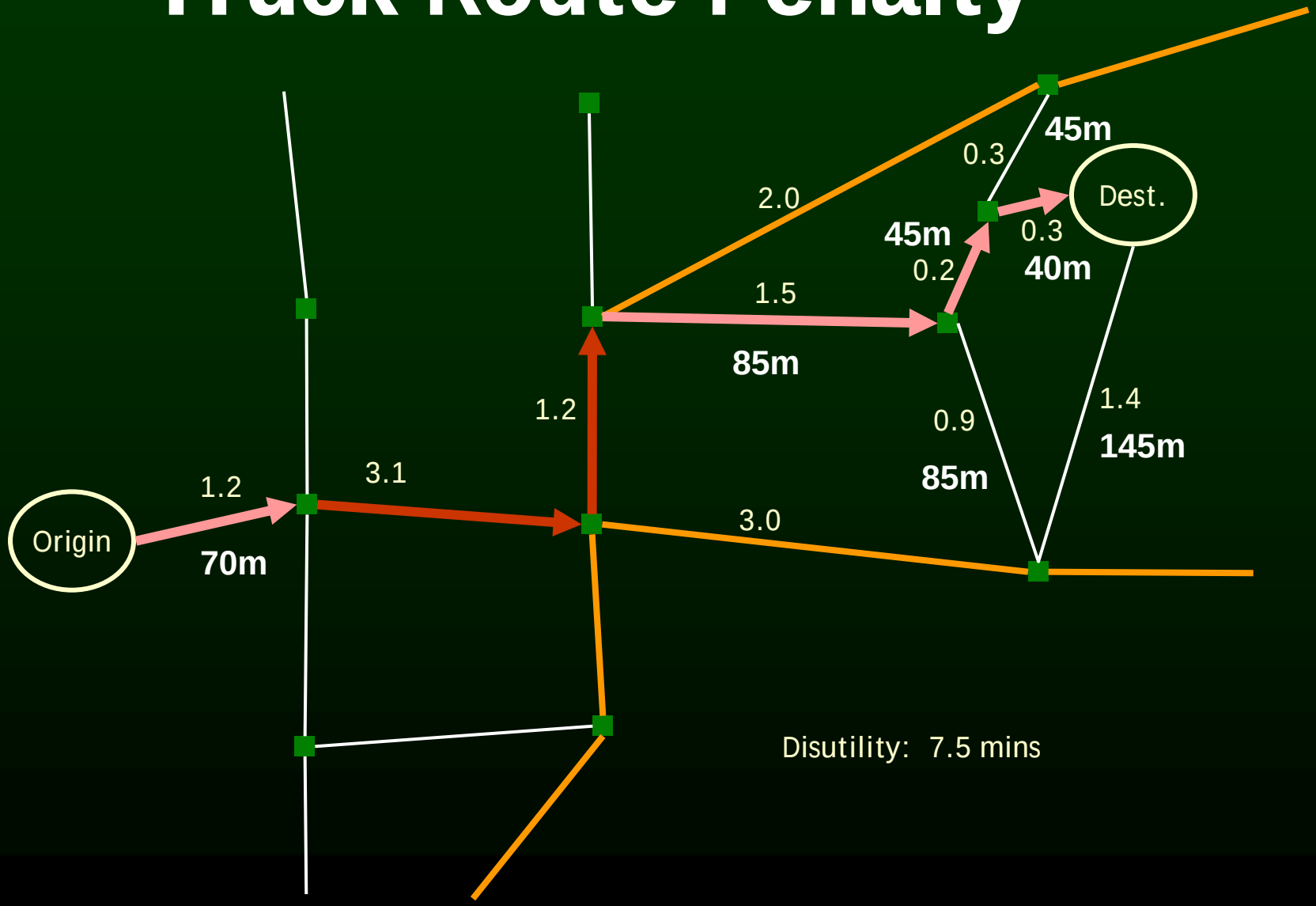

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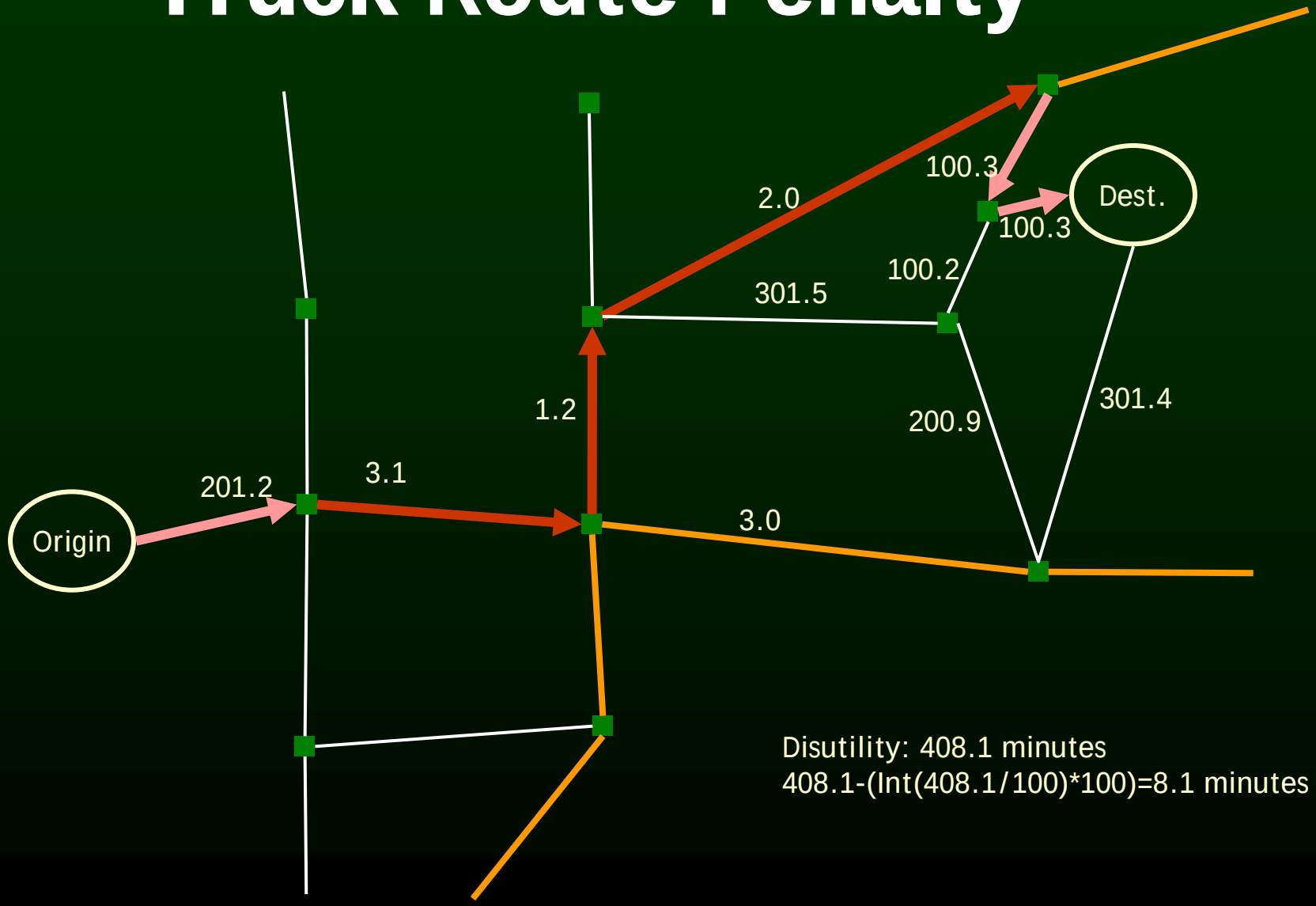
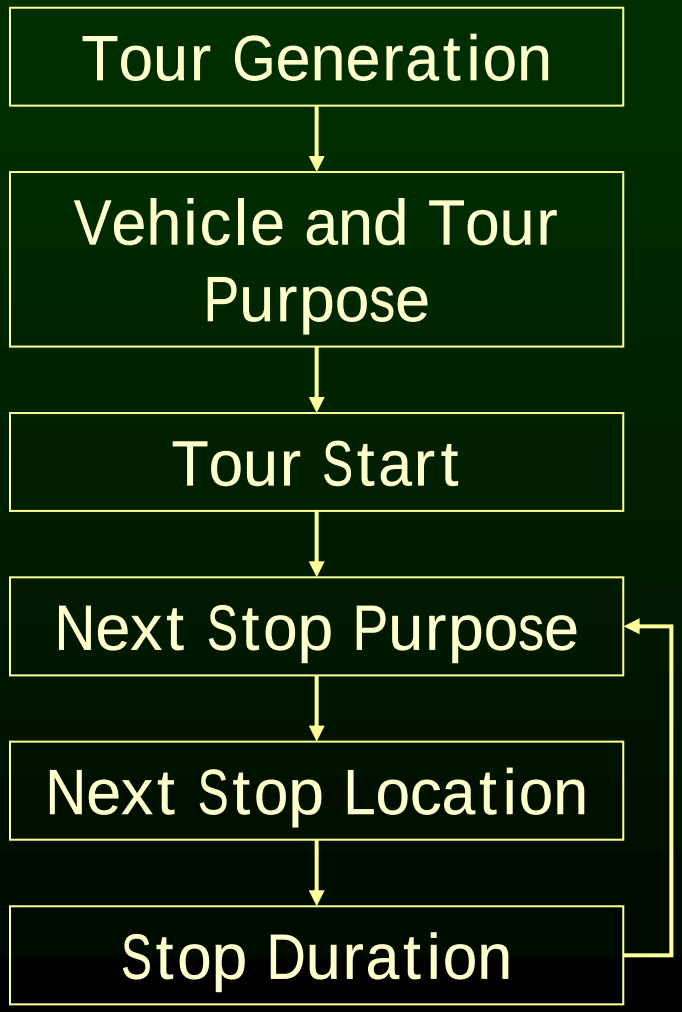


Disutility: 408.1 minutes
408.1-(Int(408.1/100)*100)=8.1 minutes

Tour-Based Microsimulation



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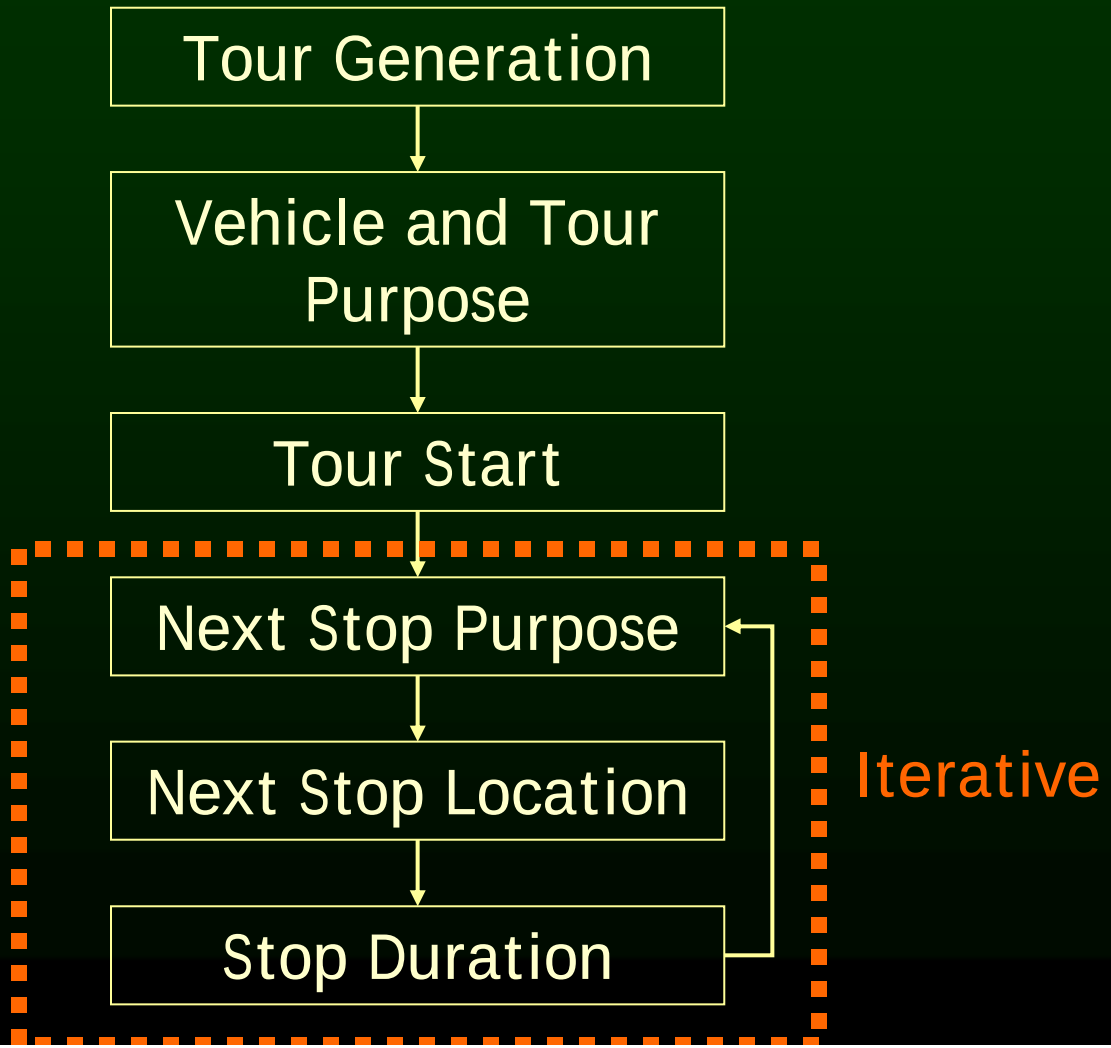

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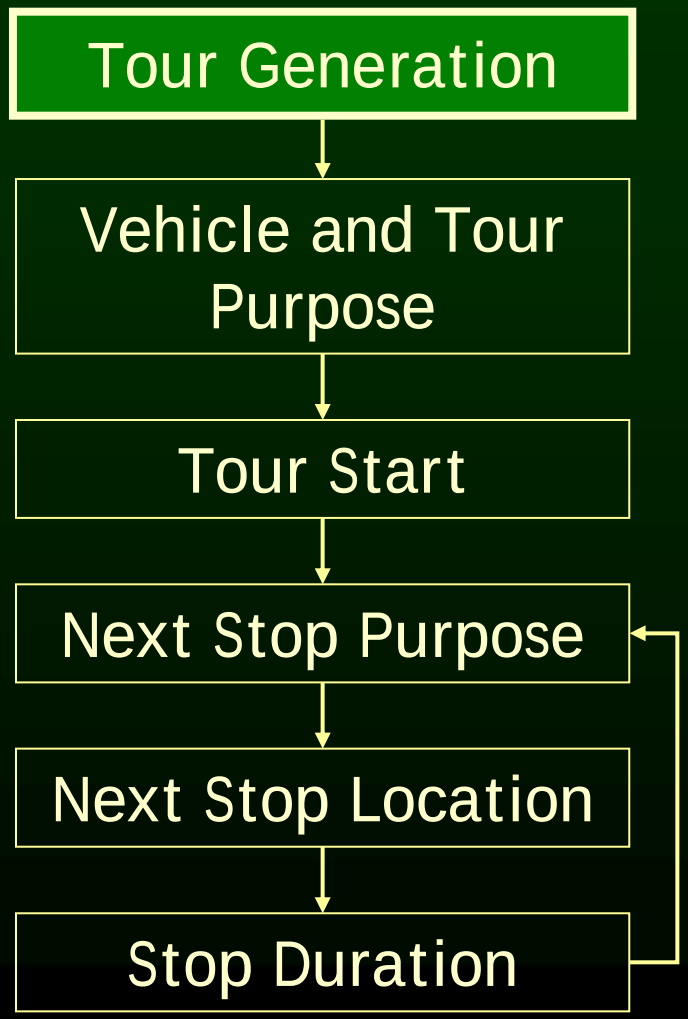
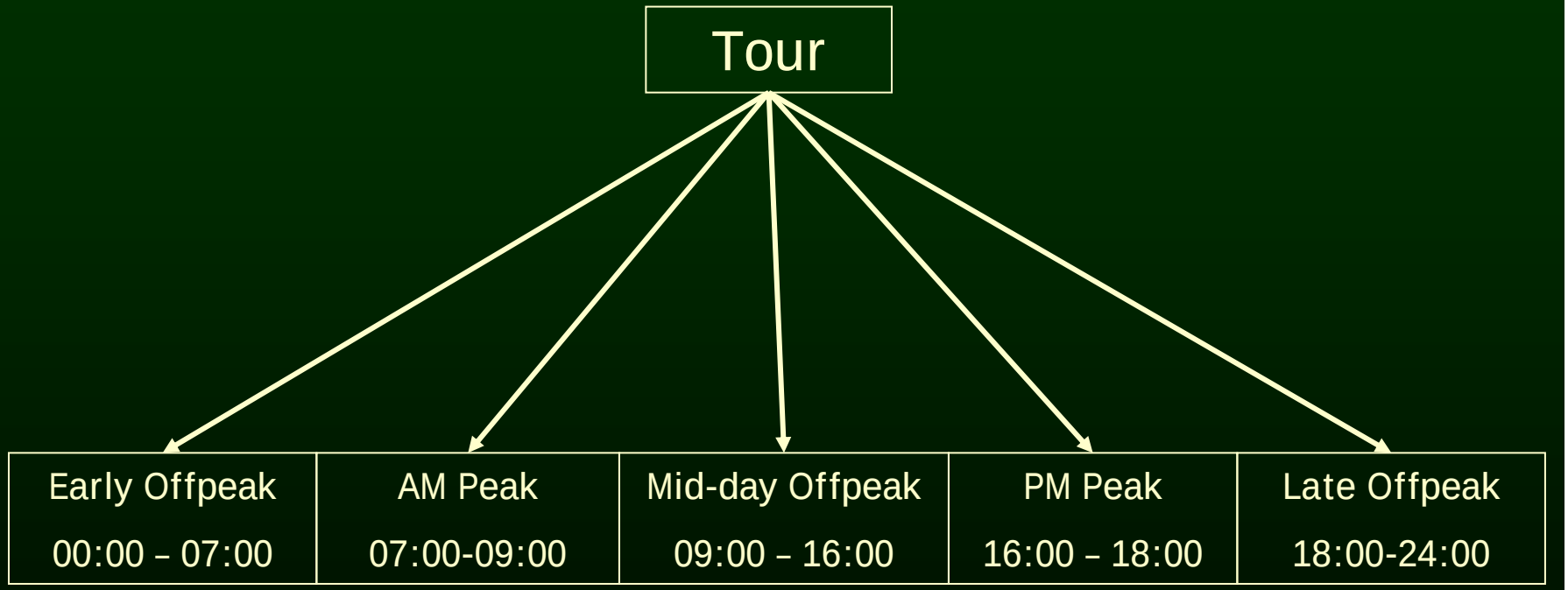


Tour Generation

- Exponential regression used to estimate tours generated per employee per day at a zonal level
- Attributes include:
  - Land use type, as proxy for occupations
  - Accessibilities to population and employment
    - Signs are –ve!
    - Implications for evaluation
  - Proportion of workers in a given industry

Tour Start Time Period

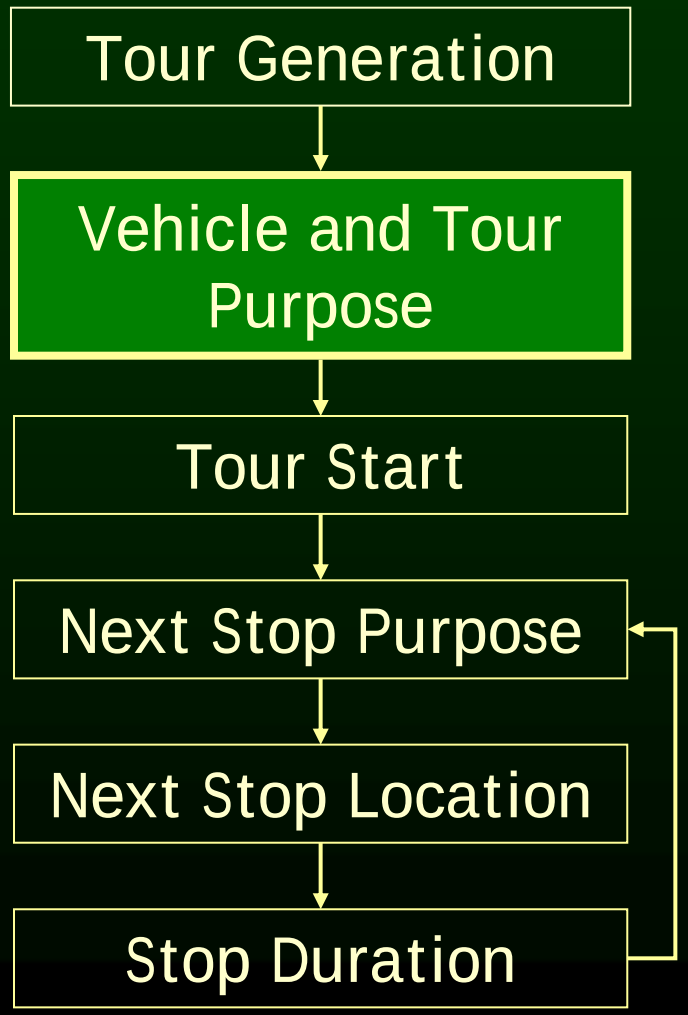


Tour Start Time Period

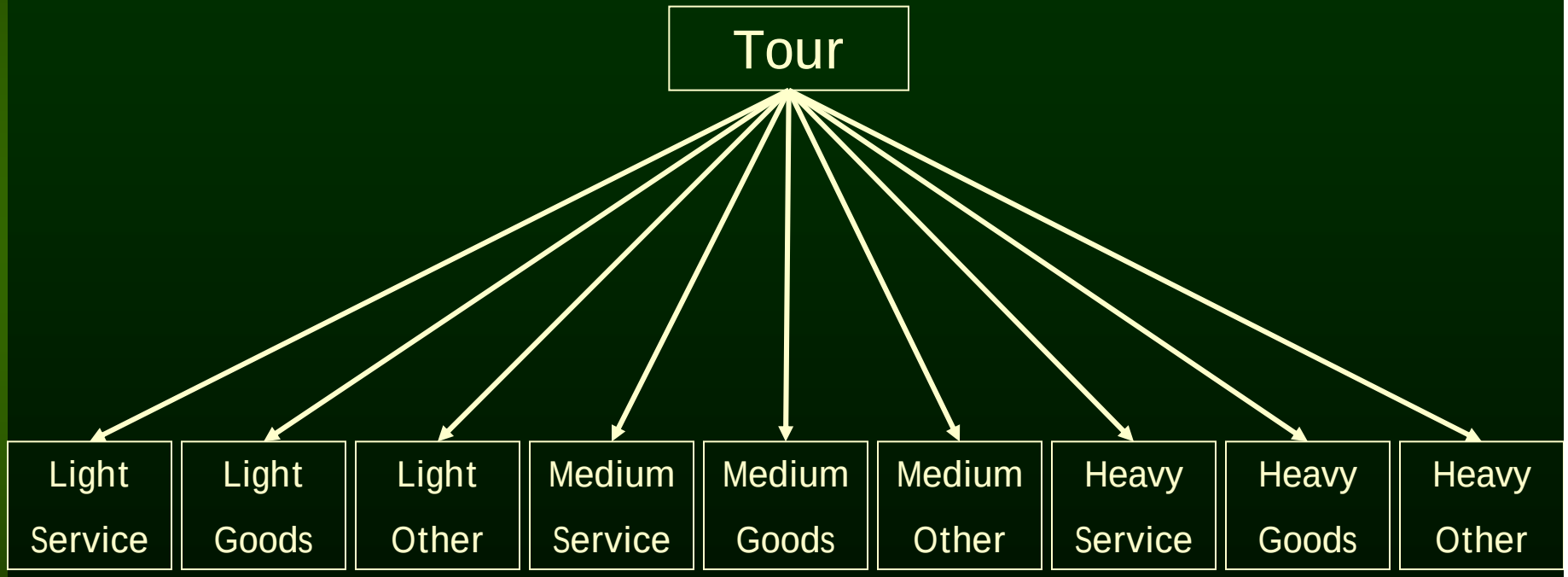
attributes in utility function:

- Land Use Type
- Accessibilities to population and employment
- Proportions of workers by industry
- Alternative Specific Constants
  - ‘Largist role’
  - Fairly fixed patterns

Tour-Based Microsimulation



Vehicle Type and Tour Purpose

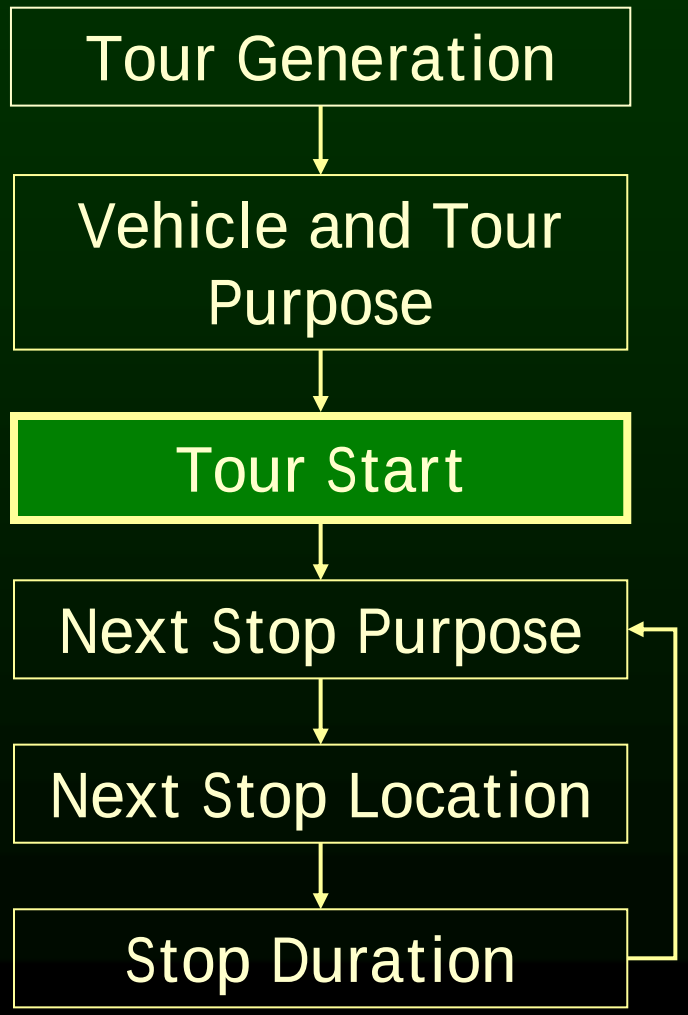


Vehicle Type and Tour Purpose

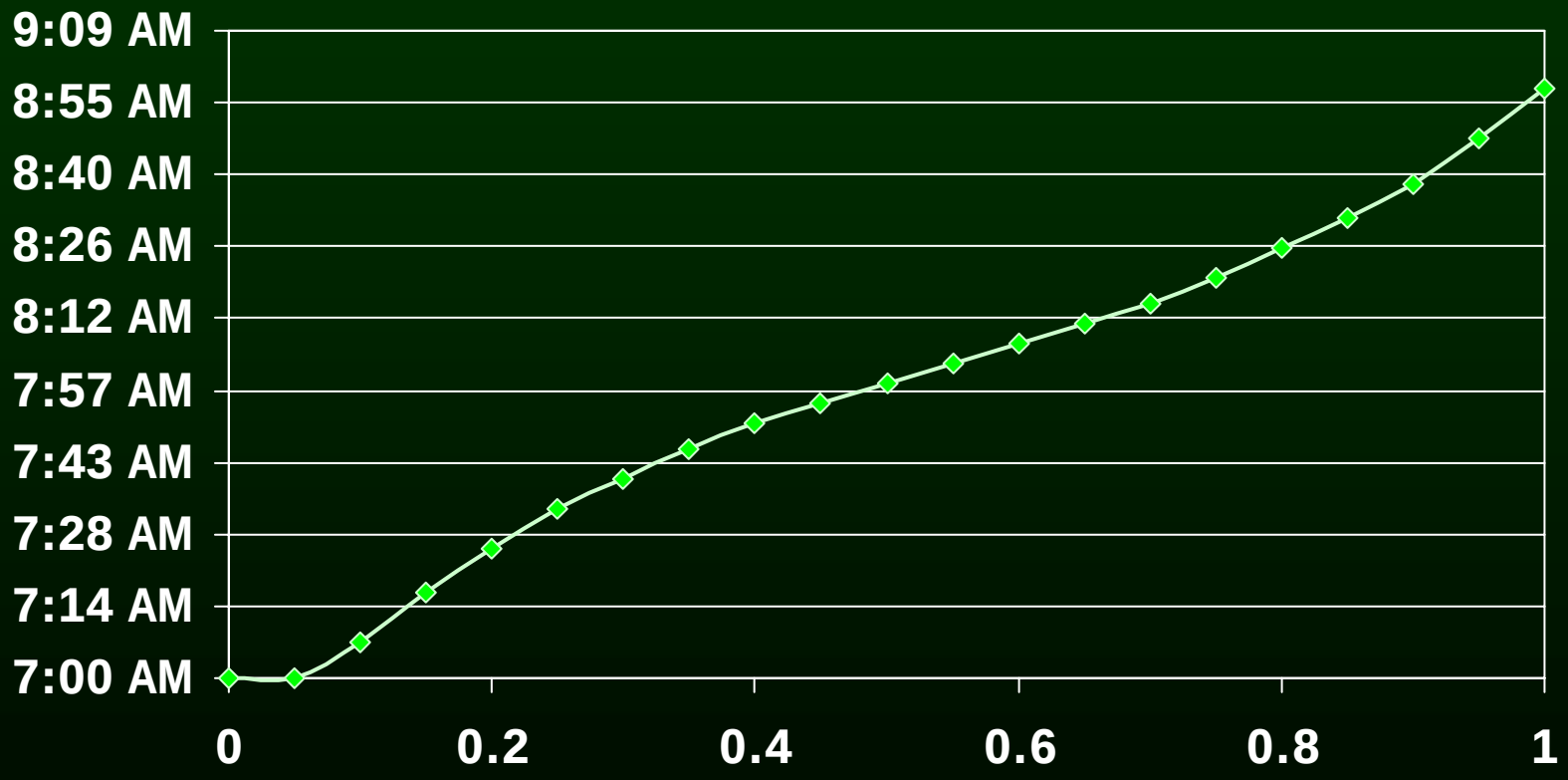
attributes in utility function:

- Land Use Type
- Accessibilities by vehicle type
- Proportions of workers by industry
- Alternative Specific Constants

Tour-Based Microsimulation



Tour Start - AM Industrial



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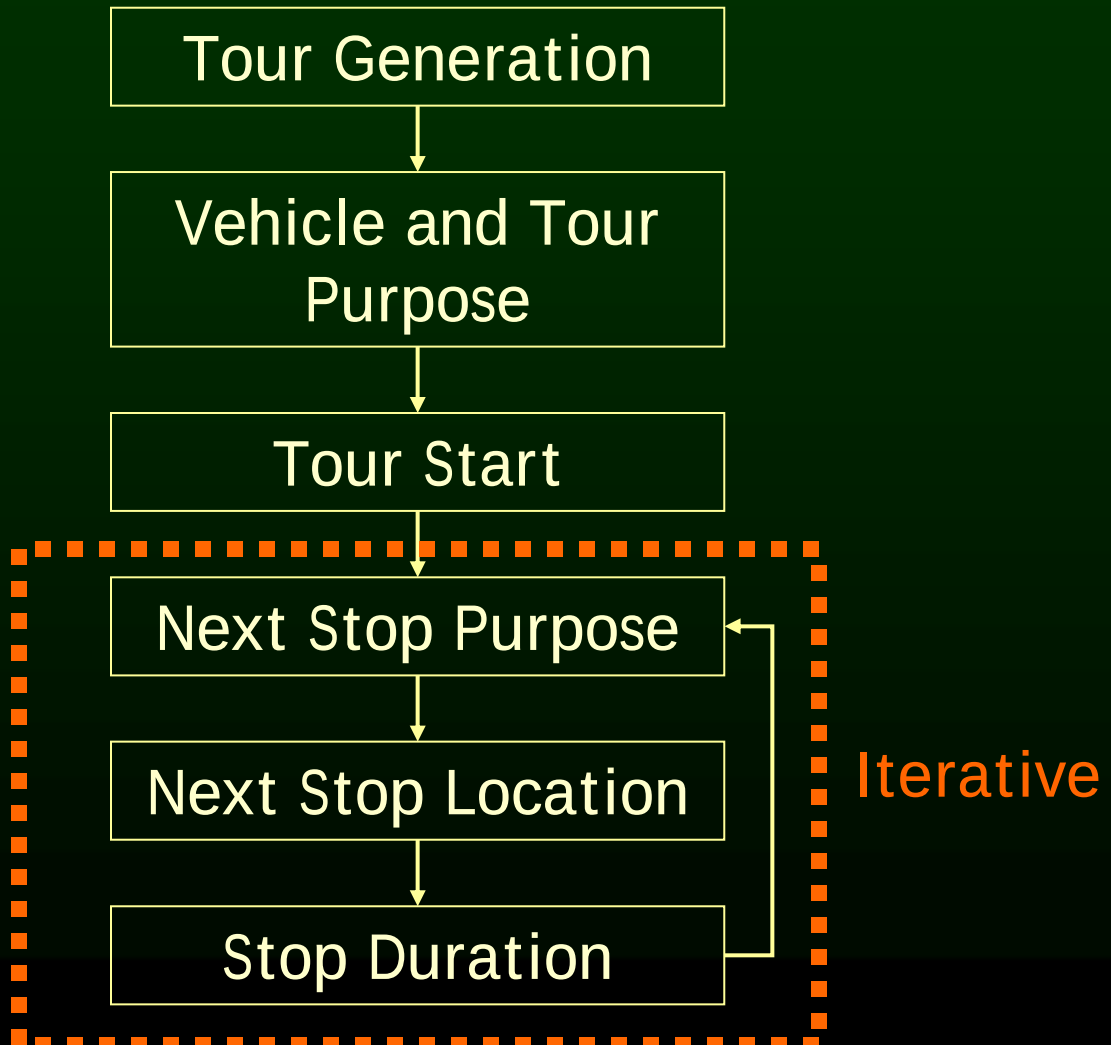

Commercial Model Segments

<table>
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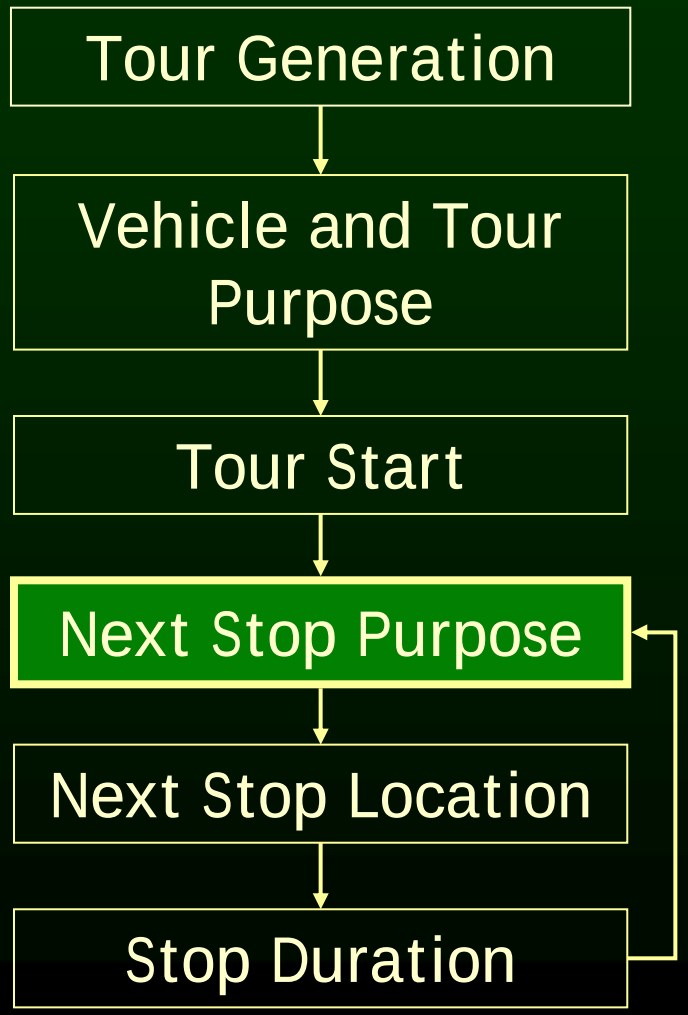
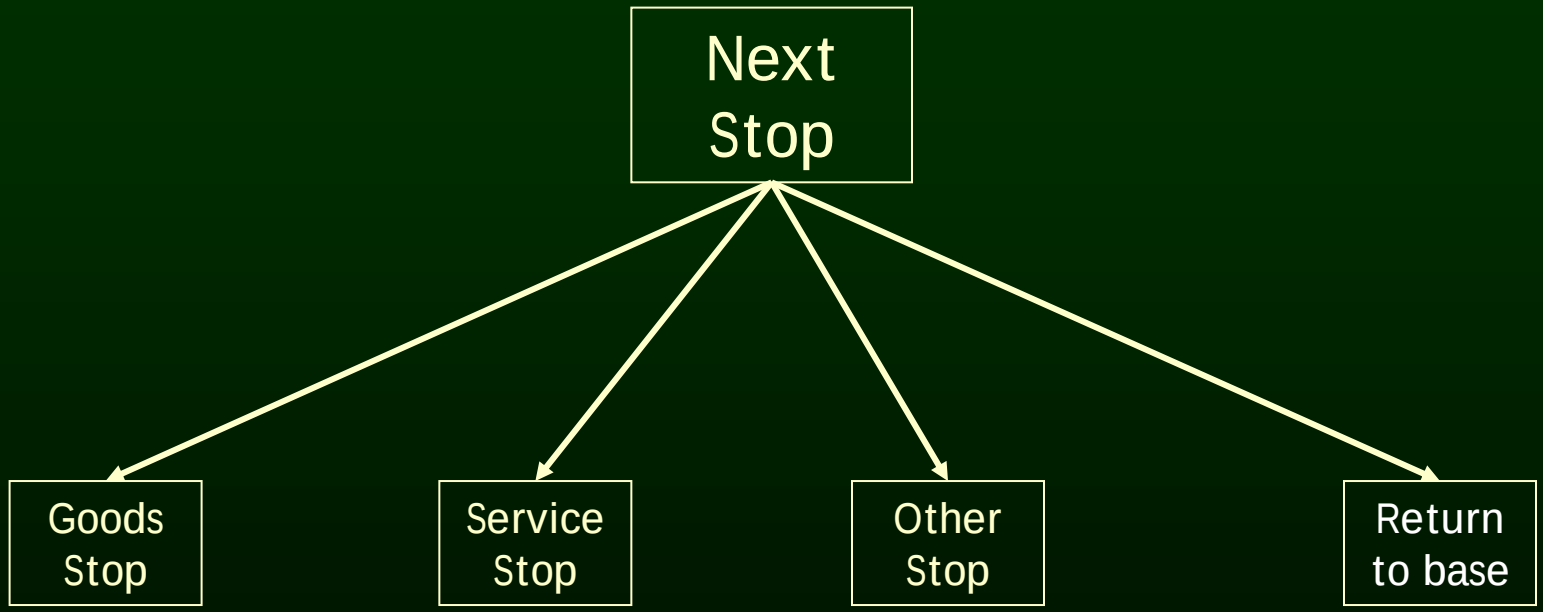


Next Stop Purpose



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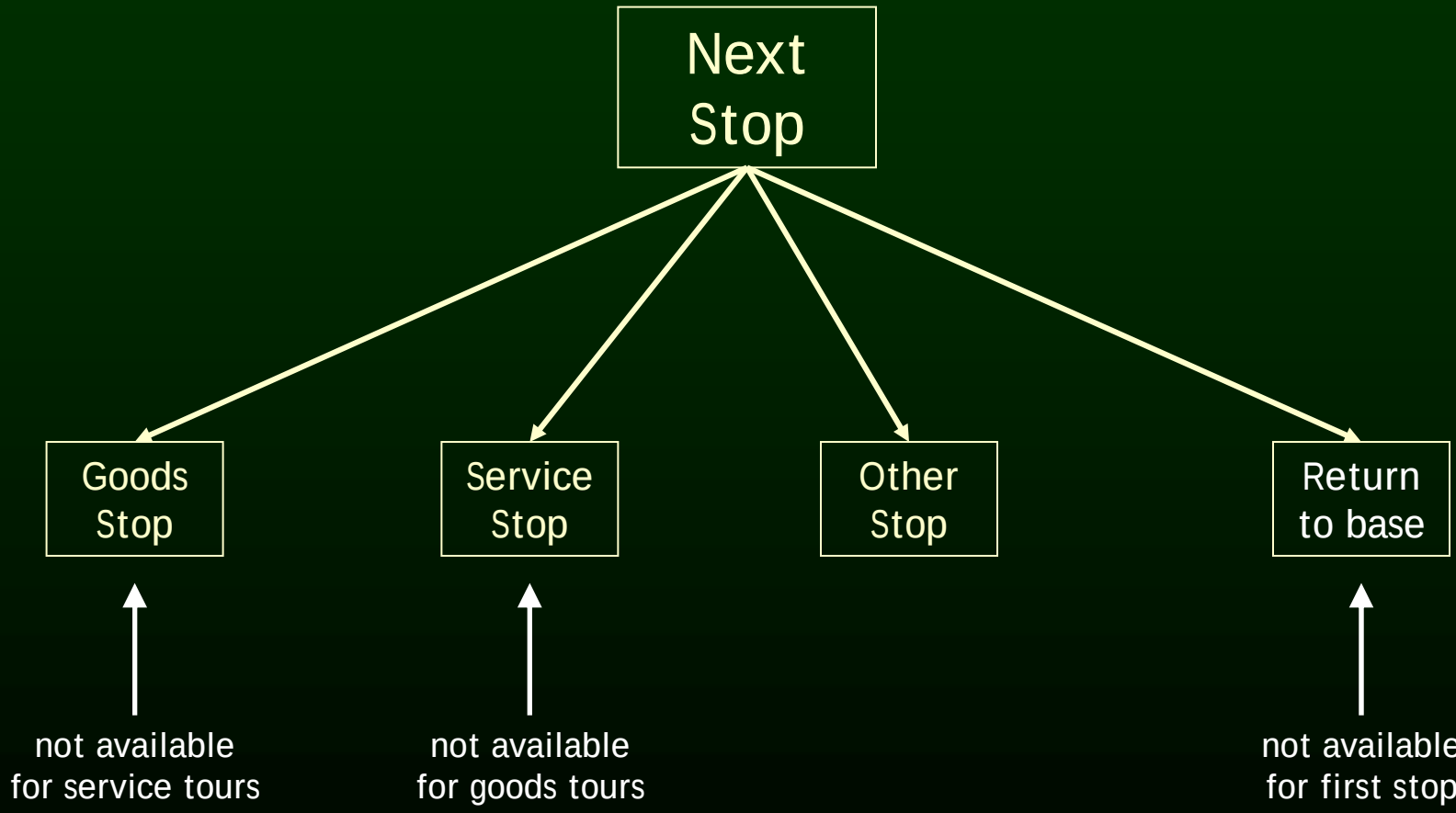


Next Stop Purpose

attributes in utility function:

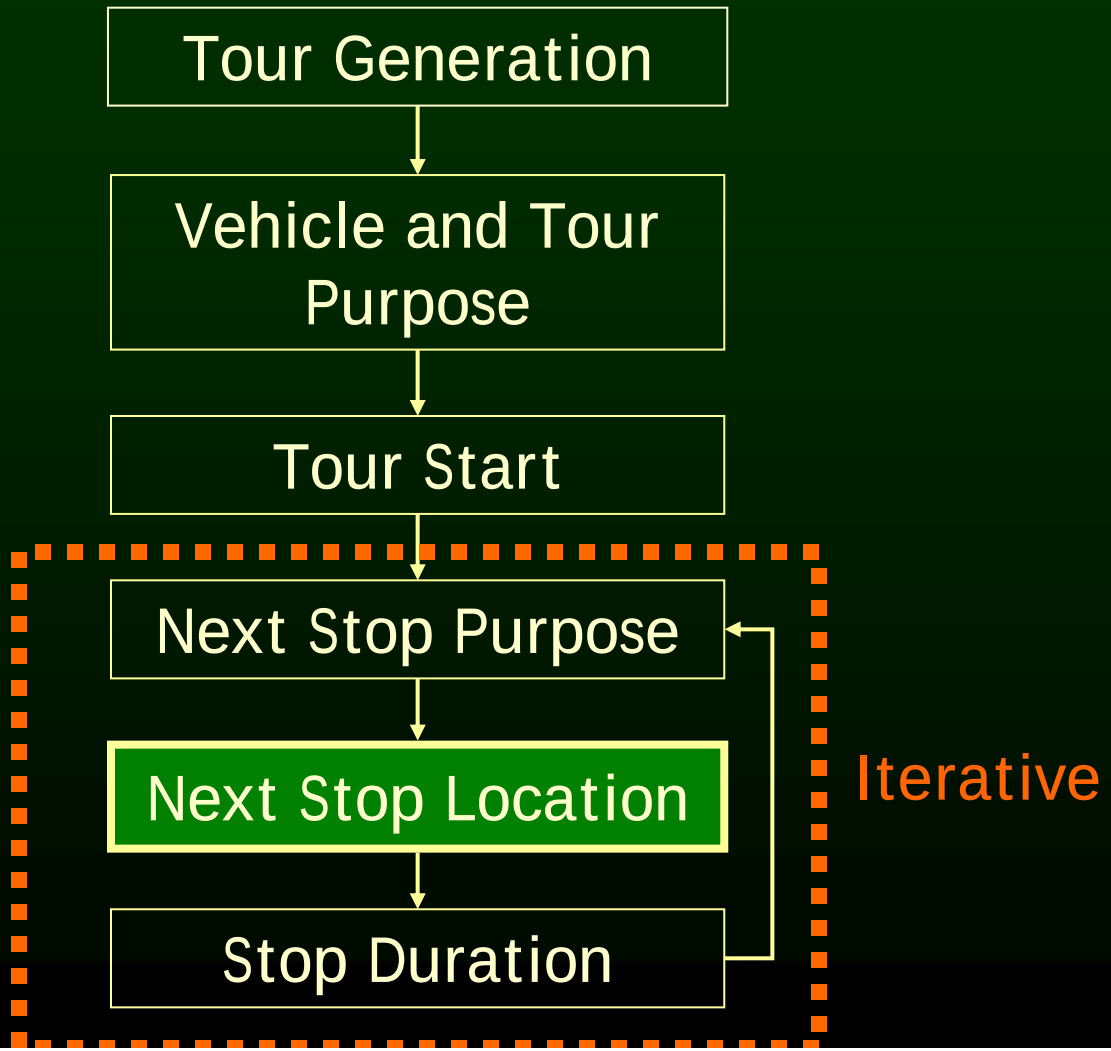
- Elapsed Total Time since start of tour
- Elapsed Total Travel Time since start of tour
- Number of stops by type since start of tour
- Time Period
- Accessibilities for current stop location
- Generalized Cost for vehicle trip to return to establishment
- Alternative Specific Constants

Next Stop Purpose Choice

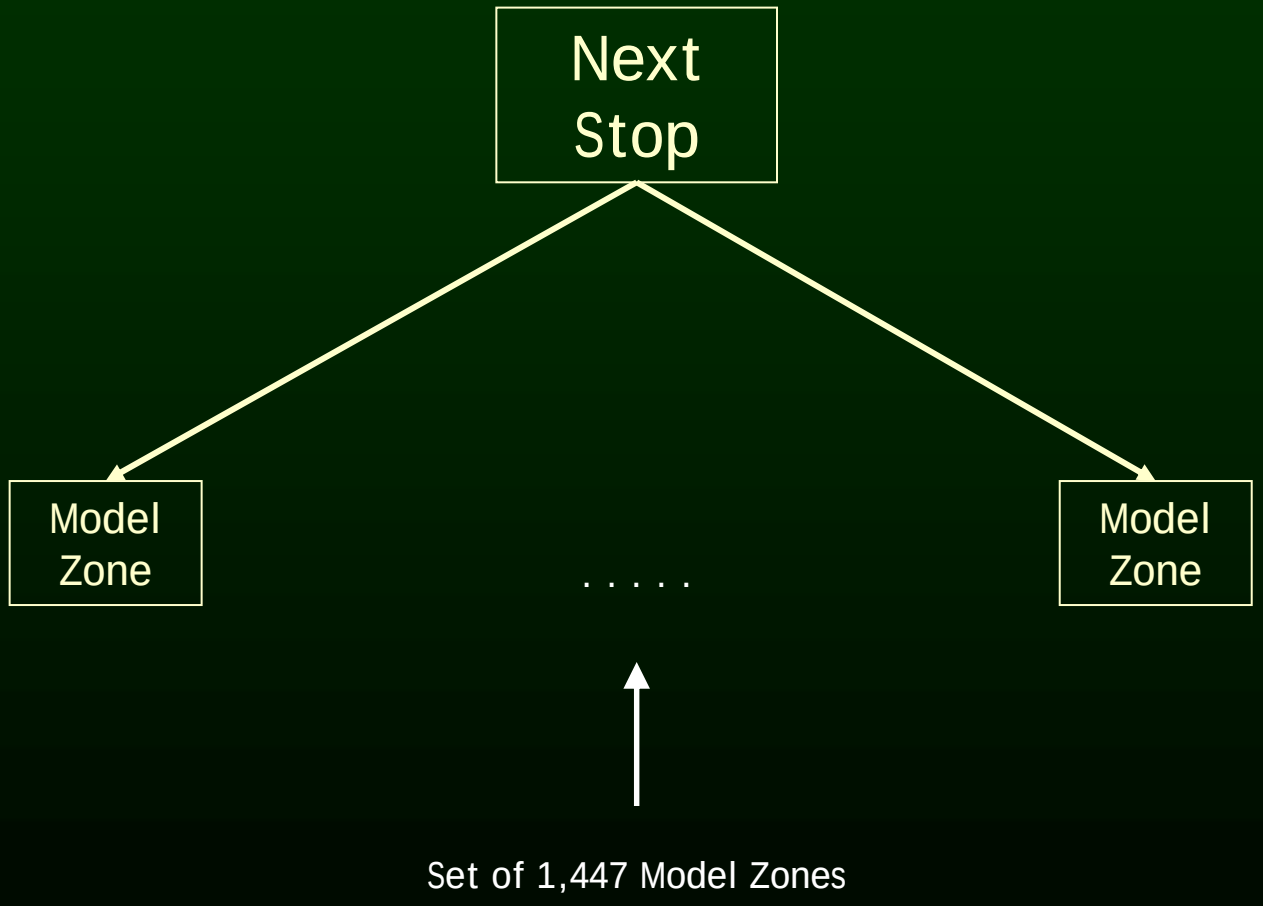
Next Stop Purpose Coefficients t-ratio < 1.96 ; 1.96 < t-ratio < 3.29

Firm-Tour-Veh Types	Business ASC	Return ASC	Business previous stops	Other previous stops	Total previous stops	Total Elapsed time	Total Travel time ($\times 10^{-3}$)	Other Total Elapsed time	Return gen. cost ($\times 10^{-3}$)	Accessiblity to Employment
All-Other-LMH		4.083			-3.380	0.7893		0	2.6960	7.015×10^{-7}
PS-S-L	2.936	2.639	0.3514	0.272	-1.045	0.2539	5.969	0.1046	0.3981	
PS-S-MH	2.352	2.162	0.4774	1.053	-0.777	0.3402	2.587	0.1048	0.6057	
PS-G-LMH	2.284	1.648	1.1330	1.336	-0.517	0.3909	6.431	0.2716	0.1106	
R-S-LMH	2.707	2.619	0.6021	0.920	-0.111	0.1837	-0.899	0.1532	0.5538	
R-G-LMH	3.725	3.411	0.1141	1.557	-1.519	0.2083	8.930	-0.1128	-0.3348	
I-S-L	2.525	2.978	1.0750	1.121	-0.924	0.3525	3.123	0.2234	0.3253	
I-S-MH	2.599	2.364	0.0615	1.202	-1.133	0.3025	9.960	0.1187	1.0750	
I-G-LMH	2.890	3.041	0.3996	0.959	-1.127	0.2748	4.555	0.1103	0.3335	
W-S-LMH	2.302	2.028	0.9692	1.159	-0.346	0.3419	2.754	0.1509	0.9744	
W-G-L	3.448	1.823	0.4821	1.412	-0.493	0.2715	4.501	-0.1719	0.1402	
W-G-MH	2.984	1.687	0.3894	1.316	-0.467	0.1746	10.280	0.006591	0.2118	
T-X-LMH	2.901	2.541	1.3950	2.174	0.0637	0.2944	1.819	0.2447	0.7048	

Tour-Based Microsimulation



Next Stop Location

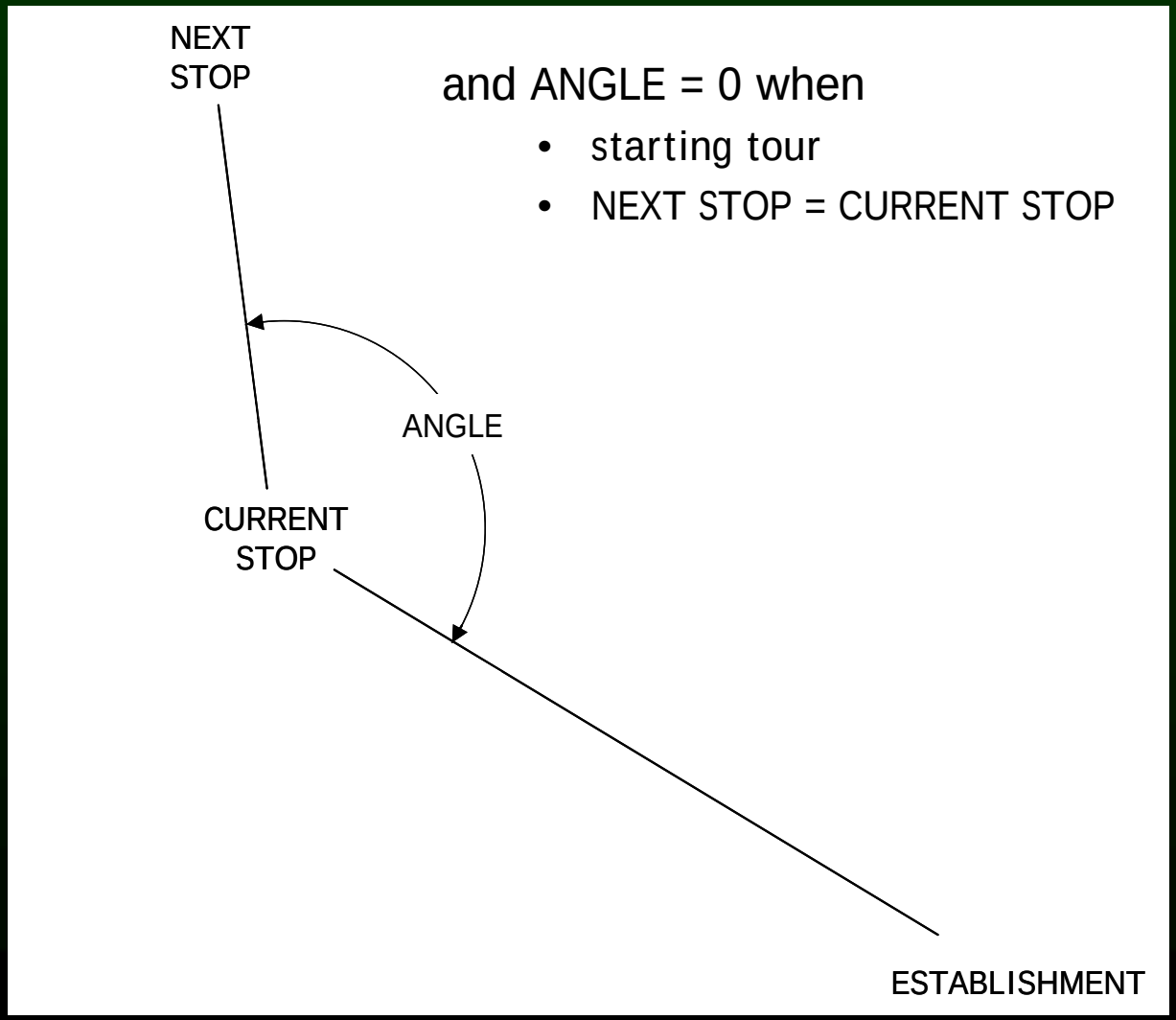


Next Stop Location Choice Model

attributes in utility function:

- Generalized Cost for vehicle trip to potential stop location
- Generalized Cost for vehicle trip to return to establishment from potential stop location
- Population and employment accessibilities
- Land use type
- Average income for households at potential stop
- Population and employment size terms
- Enclosed Angle

Angle Measure

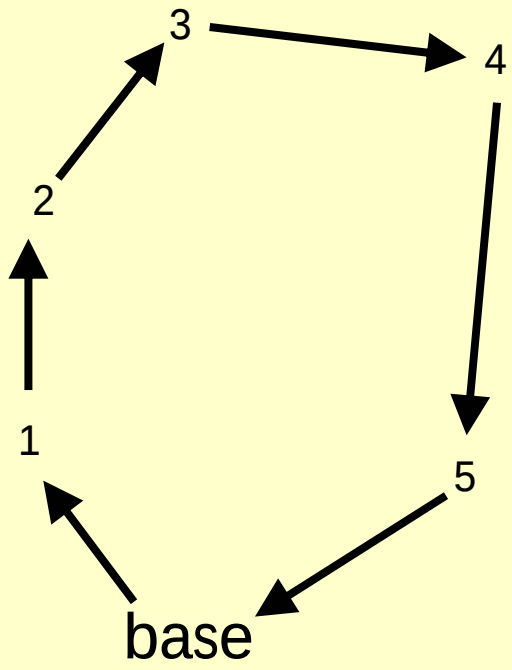


Next Stop Location Choice

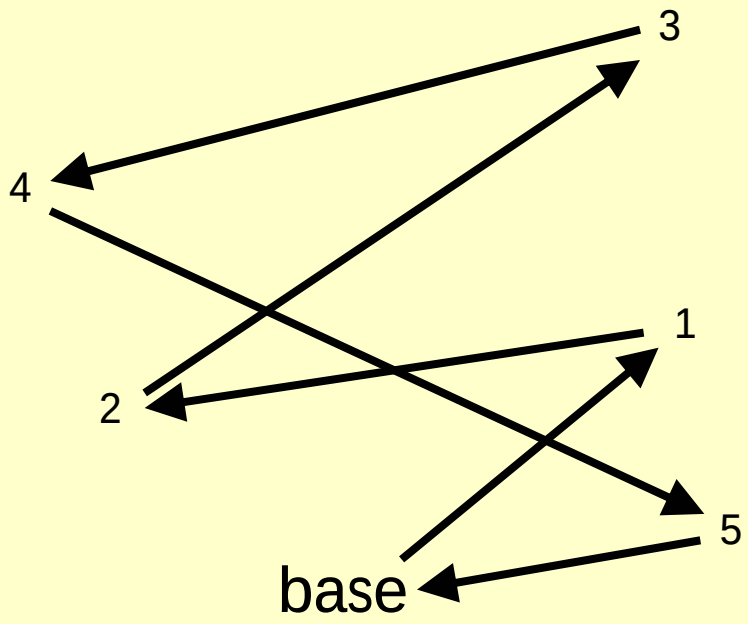
Next Stop Location Choice Model Coefficients t-ratio < 1.96 ; 1.96 < t-ratio < 3.29

Firm-Tour-Veh Types	Low Den land use	CommRet land use	Ind land use	EmpNode land use	AveInc ($\times 10^{-6}$)	GenCost travel to next stop	GenCost return to base	Pop Access ($\times 10^{-6}$)	Emp Access ($\times 10^{-6}$)	Enclosed Angle ($\times 10^{-3}$)	Size Term	Emp Size Term ratio
All-Other-LMH	-.7902	.0270	-.1595	-.6126	-11.490	.3039	.1310	-7.651	-9.696	-2.346	.2800	6.779
PS-S-L	-.0898	-.2755	.2152	-.4623	1.676	.3283		-10.83	-2.653	-1.884	.3094	.087
PS-S-MH	.7250	-.1057	.4655	-.7546	9.476	.0848	.1229	-44.65	9.296	3.684	.2219	
PS-G-LMH	-.3327	.5674	.4926	.2062		.5688		5.717	-16.54	-6.348	.1588	
R-S-LMH	-.9676	-.2310	.1547	-.5132		.3601	.03662	-17.35	0	-1.241	.2841	.633
R-G-LMH	-.1707	-.0256	.8014	-.1840		.3734	.09158	-13.32	-1.682	1.914	.2067	1.633
I-S-L	-1.144	-.2361	.0503	-.4182		.2869		-24.98	5.477	-3.067	.2371	1.231
I-S-MH		-.3231	.2789	-.8438		.1627	.1279	-13.25	-16.96	2.934	.1205	1.012
I-G-LMH		-.1497	.5575	-.2042		.2581	.09615	-10.68	-5.139	-2.146	.2722	
W-S-LMH	-.9340	-.2130	.1440	-.4410	2.367	.3849	.04300	-11.81	-27.71	1.761	.2426	2.138
W-G-L	-.6668		.9271	-.2688		.4495	.1075	-32.84	-67.74	.892	.2248	
W-G-MH	-.1226		.1445	-.1183		.3123	.03430	-31.84	5.950	-1.431	.3021	2.313
T-X-LMH	-.5279	.1004	.6275	.0267	-4.691	.3792		-11.72	-5.984	3.109	.0087	

Commercial Stop Location Choice
Calgary



ANG Coeff
+ve



ANG Coeff
-ve

Example Next Stop Location Utility Function

- Wholesale, Service, all vehicles
- U(zone) =
  - -0.9340 * (1 if low density zone)
  - - 0.2130 * (1 if commercial/retail zone)
  - + 0.1440 * (1 if industrial zone)
  - - 0.4410 * (1 if employment node zone)
  - + 0.000002367 * zonal average income
  - + 0.3849 * generalized cost to travel to zone
  - + 0.04300 * generalized cost for destination to return to establishment

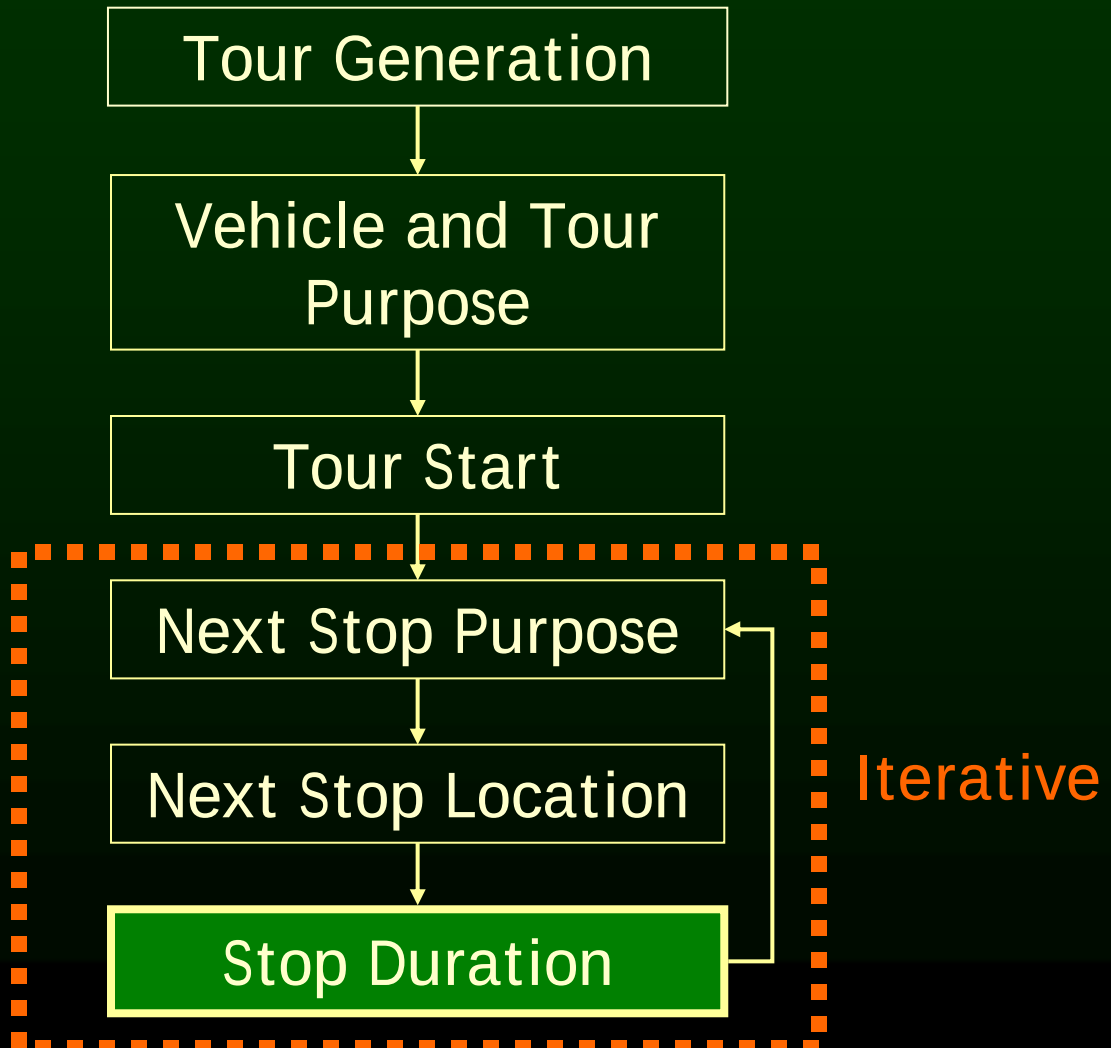
Example Next Stop Location Utility Function

- - 0.00001181 * population accessibility
- - 0.000002771 * employment accessibility
- + 0.001761 * enclosed angle (establishment - current zone - destination)
- + 0.2426 * ln (population + 2.138 * employment)

Example Next Stop Location Utility Function

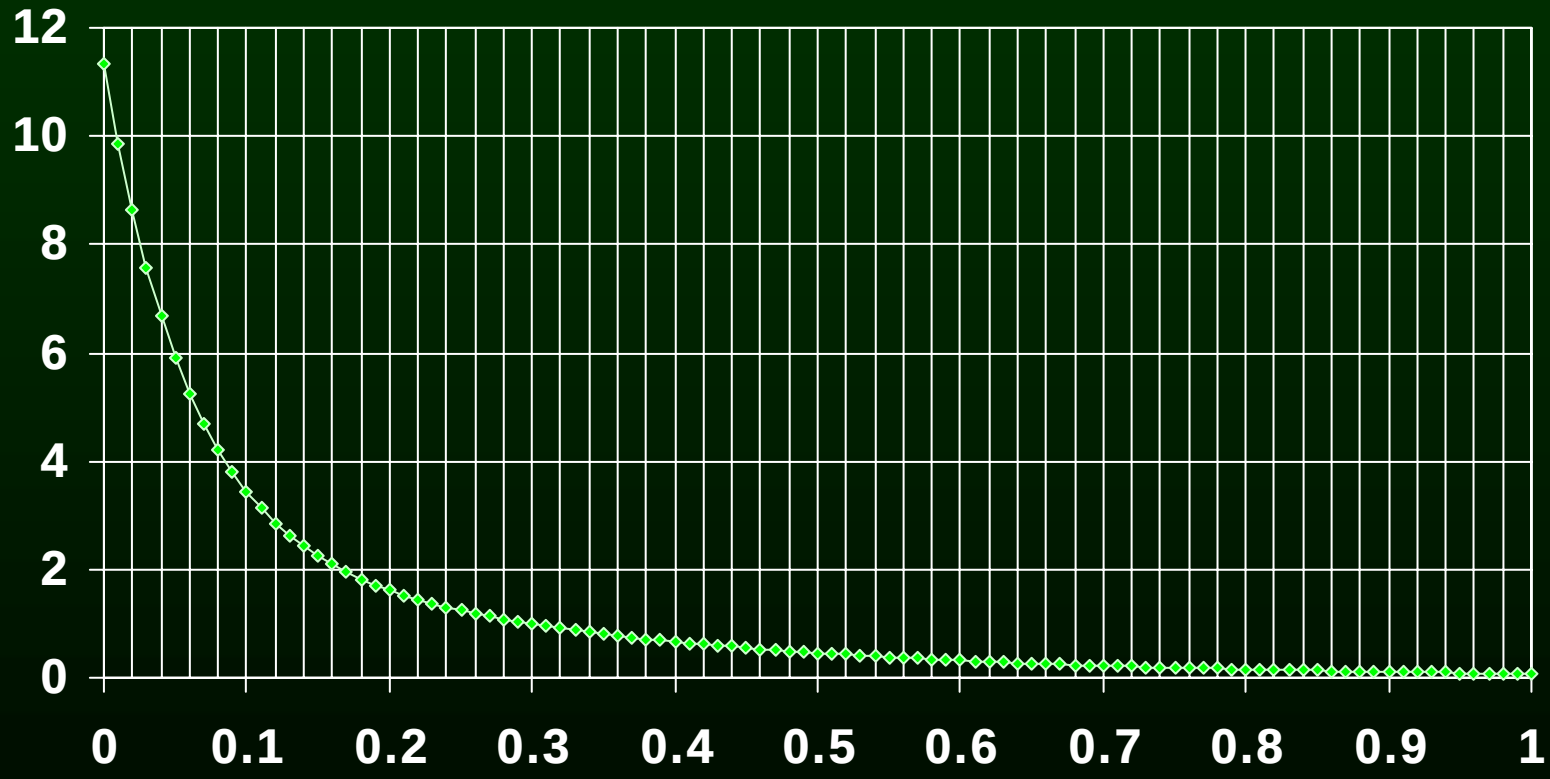
- Some of the effects:
  - Commercial vehicles are travel cost averse
  - Attracted to population and employment
  - Prefer industrial land use to anything else
  - Will stay closer to establishment (Generalized Cost for Return Trip)
  - Attracted to areas of higher income
  - Tend to travel in looping pattern away from their base

Tour-Based Microsimulation



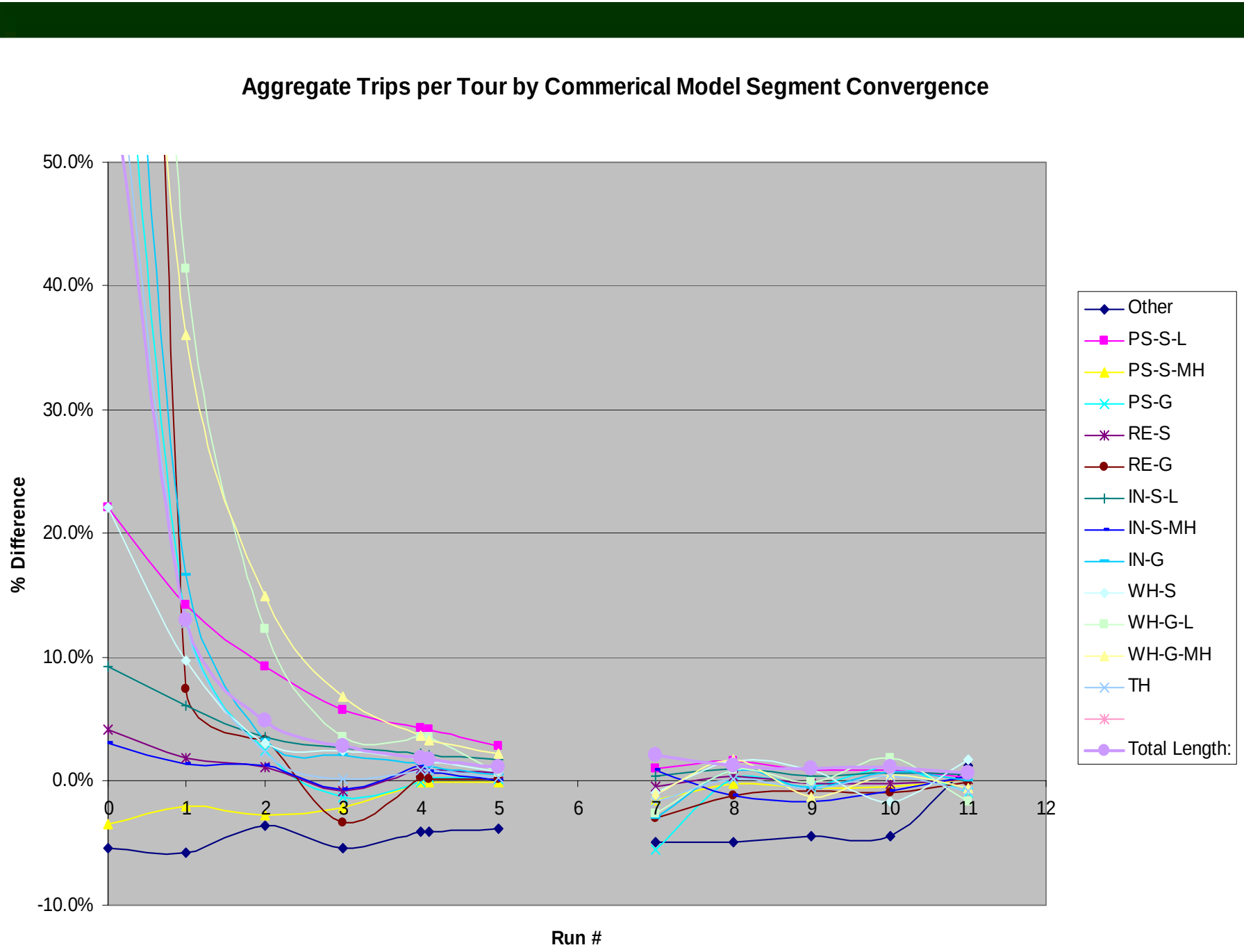
Stop Duration

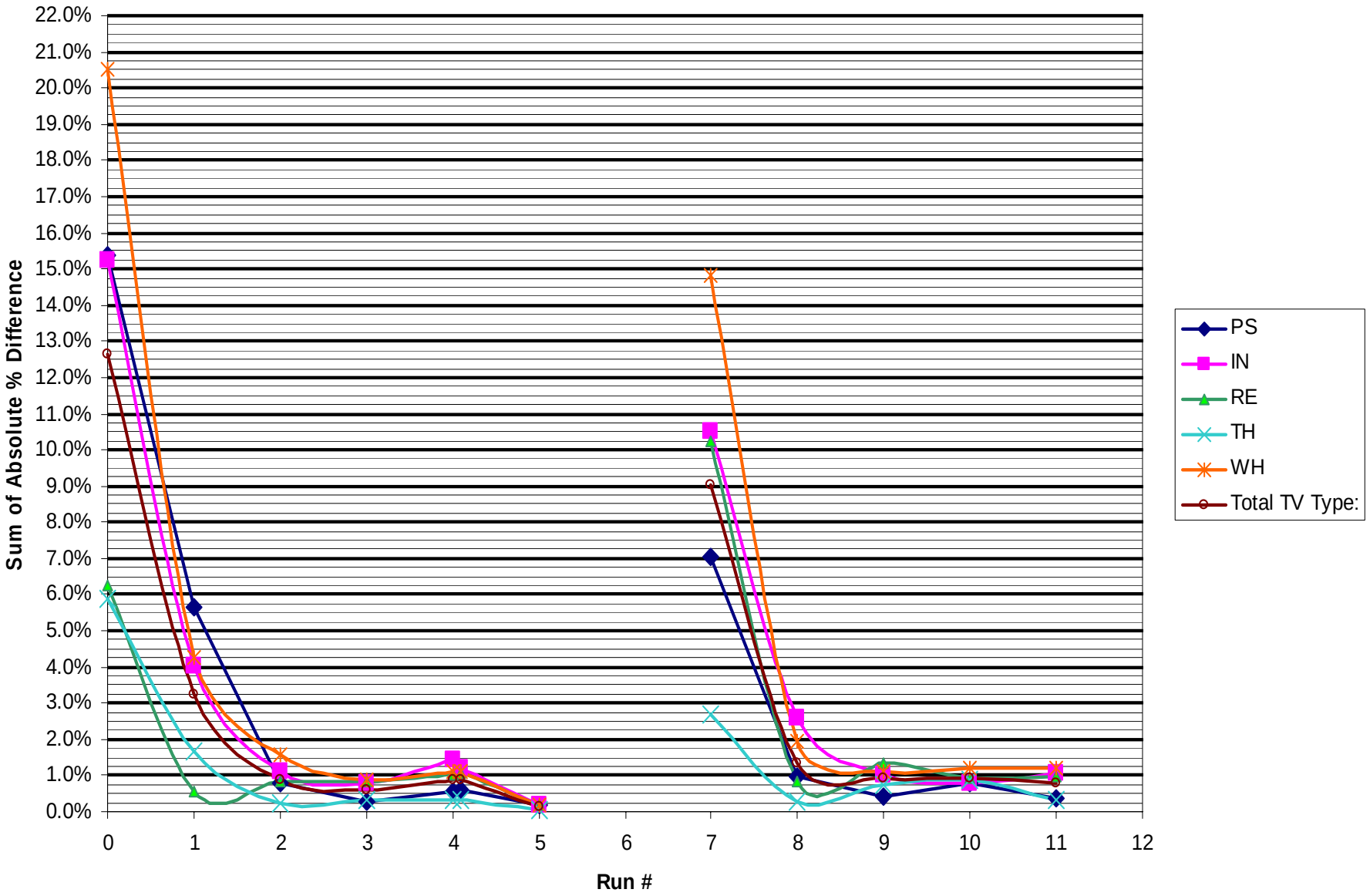
Private Service - Service - Light

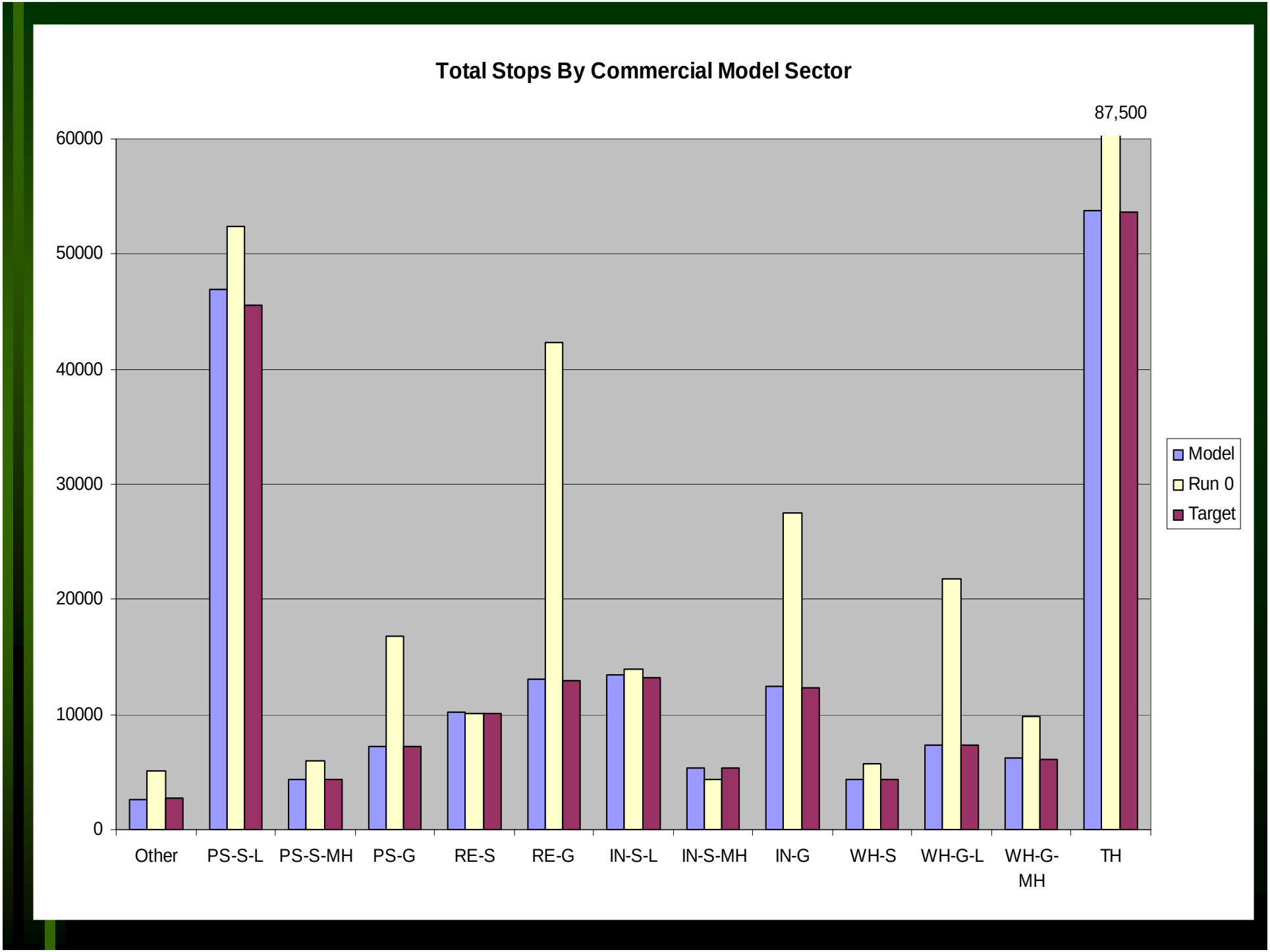


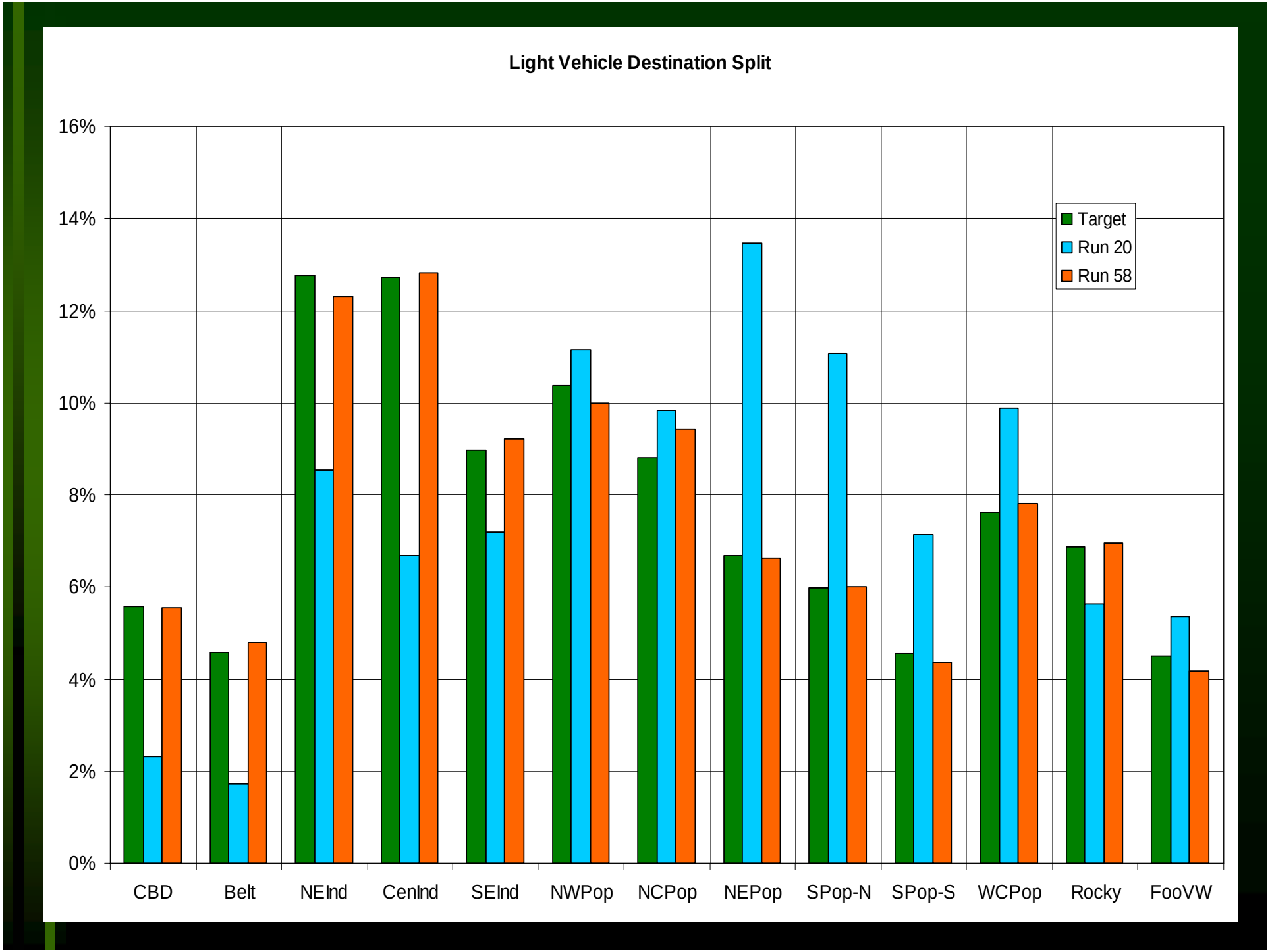
Estimation … then Calibration

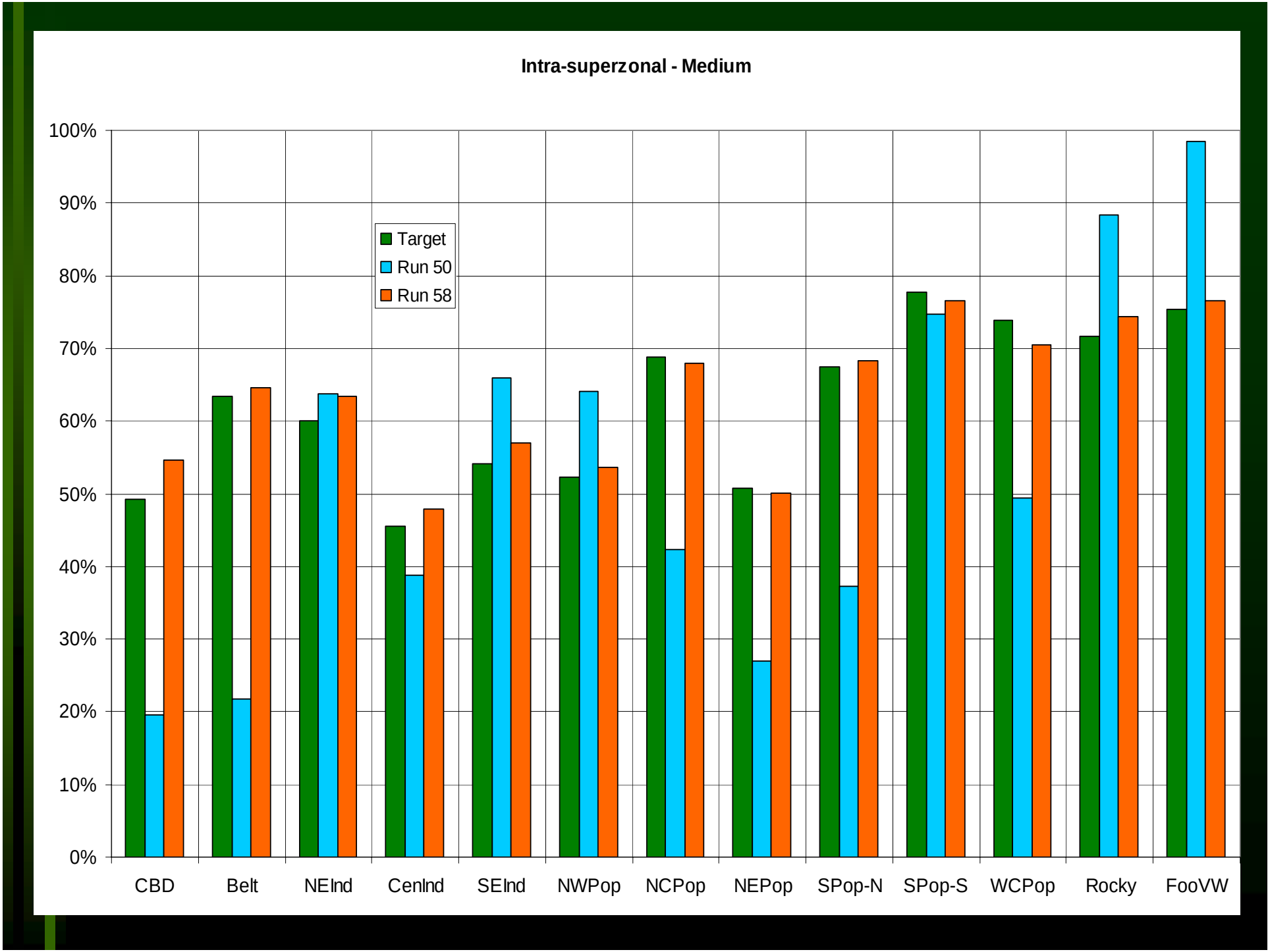
- Estimate model coefficients using choice data
- Update alternative specific constants using aggregate data
  - Trip tables from Commodity Flow Survey
  - Link counts
  - Screenline and cordon counts
- Aggregate Targets
  - Trips per tour (tour length)
  - Number of tours by vehicle type and tour purpose
  - Number of stop by commercial model segment
  - Stop locations by vehicle type and geographic sector
  - Intra-sector trips by vehicle type
  - Screenline crossings by time period


Aggregate Trips per Tour by Commerical Model Segment Convergence
% Difference
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
-10.0%
0
1
2
3
4
5
6
7
8
9
10
11
12
Run #
Other
PS-S-L
PS-S-MH
PS-G
RE-S
RE-G
IN-S-L
IN-S-MH
IN-G
WH-S
WH-G-L
WH-G-MH
TH
Total Length:


Proportion of Tours by Purpose and Vehicle Type Convergence
Sum of Absolute % Difference
22.0%
21.0%
20.0%
19.0%
18.0%
17.0%
16.0%
15.0%
14.0%
13.0%
12.0%
11.0%
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
0
1
2
3
4
5
6
7
8
9
10
11
12
Run #
PS
IN
RE
TH
WH
Total TV Type:

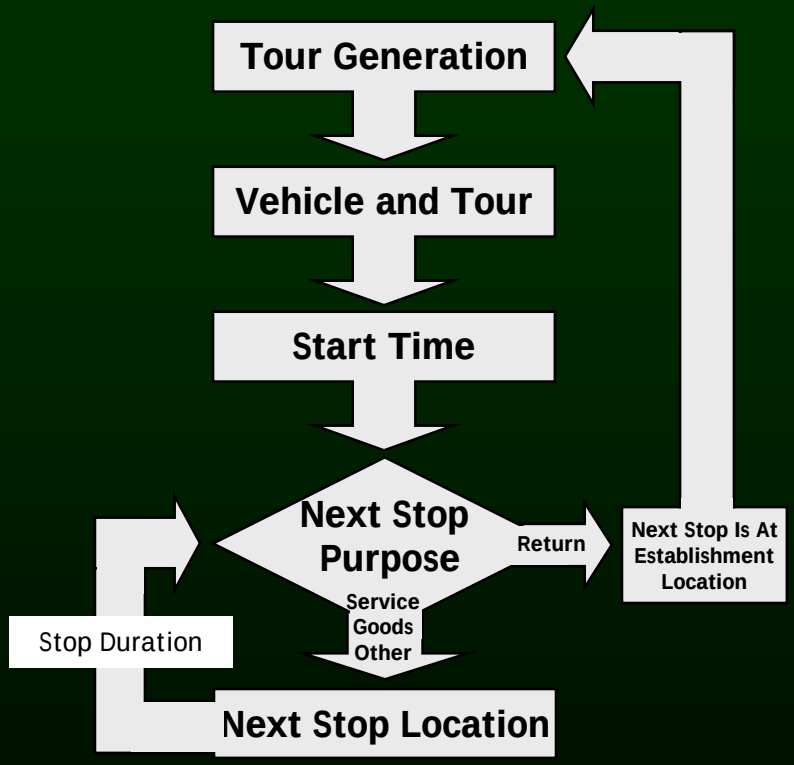

Total Stops By Commercial Model Sector
87,500
60000
50000
40000
30000
20000
10000
0
Other
PS-S-L
PS-S-MH
PS-G
RE-S
RE-G
IN-S-L
IN-S-MH
IN-G
WH-S
WH-G-L
WH-G-MH
TH
Model
Run 0
Target


Light Vehicle Destination Split
16%
14%
12%
10%
8%
6%
4%
2%
0%
Target
Run 20
Run 58
CBD
Belt
NEInd
CenInd
SEInd
NWPop
NCPop
NEPop
SPop-N
SPop-S
WCPop
Rocky
FooVW

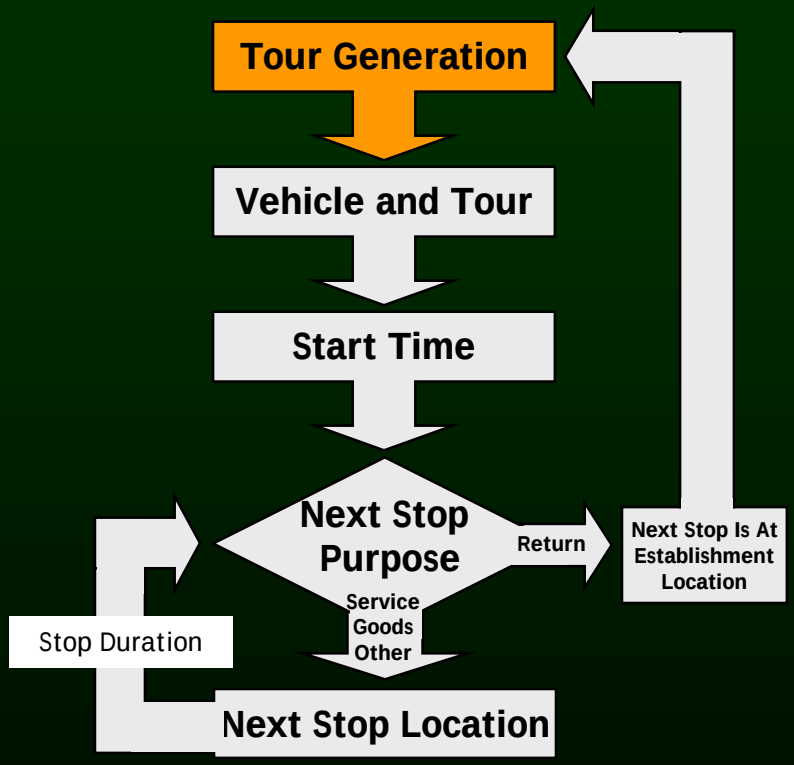

Intra-superzonal - Medium
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Target
Run 50
Run 58
CBD
Belt
NEInd
CenInd
SEInd
NWPop
NCPop
NEPop
SPop-N
SPop-S
WCPop
Rocky
FooVW


Intra-superzonal - Heavy
Target
Run 50
Run 58
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
CBD
Belt
NEInd
CenInd
SEInd
NWPop
NCPop
NEPop
SPop-N
SPop-S
WCPop
Rocky
FooVW

Microsimulation Process

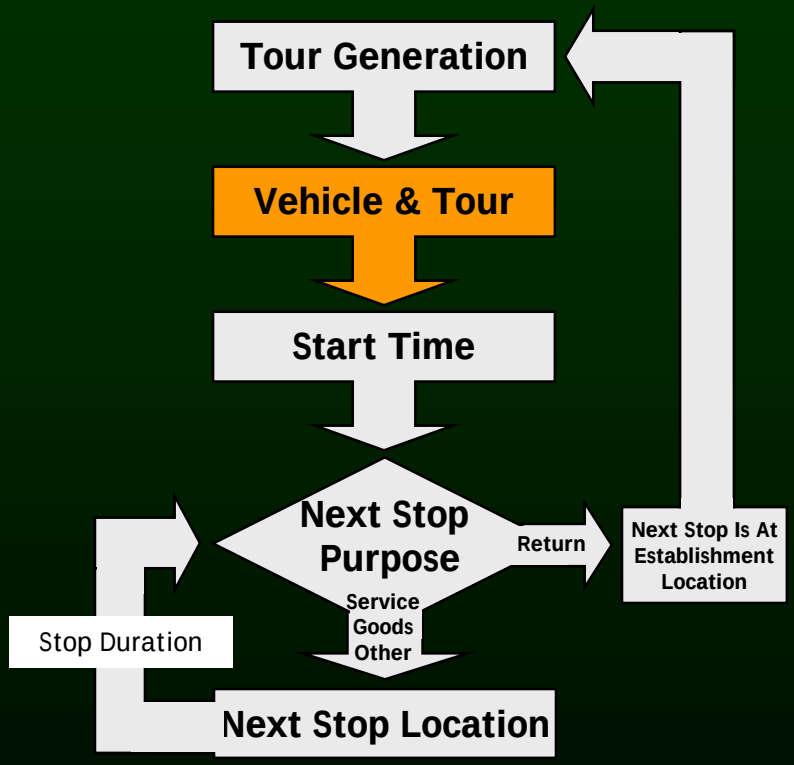


Microsimulation Process



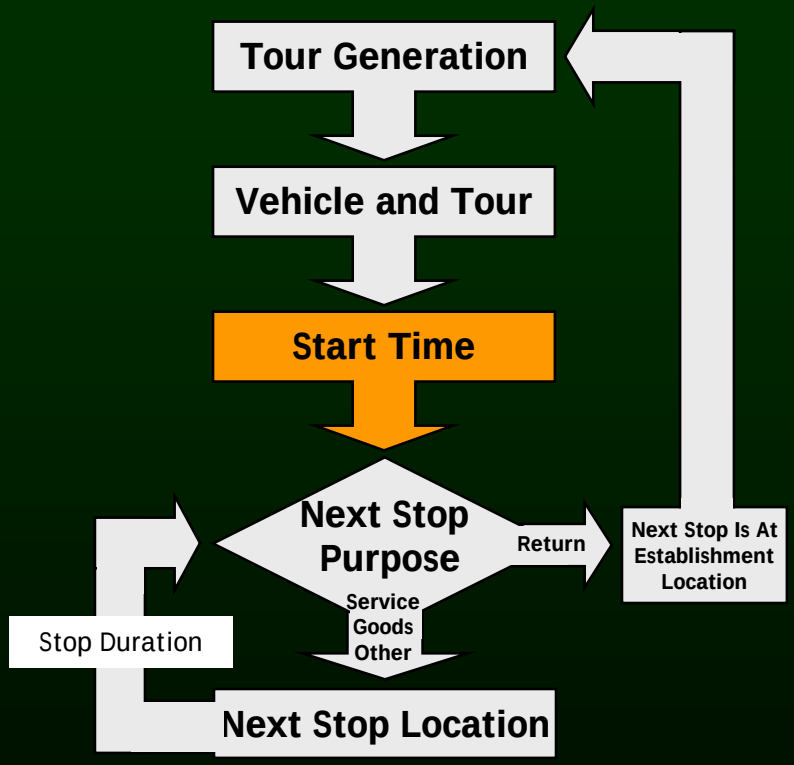
- Tour starting in zone 340 (Central Industrial) AM Peak

Microsimulation Process



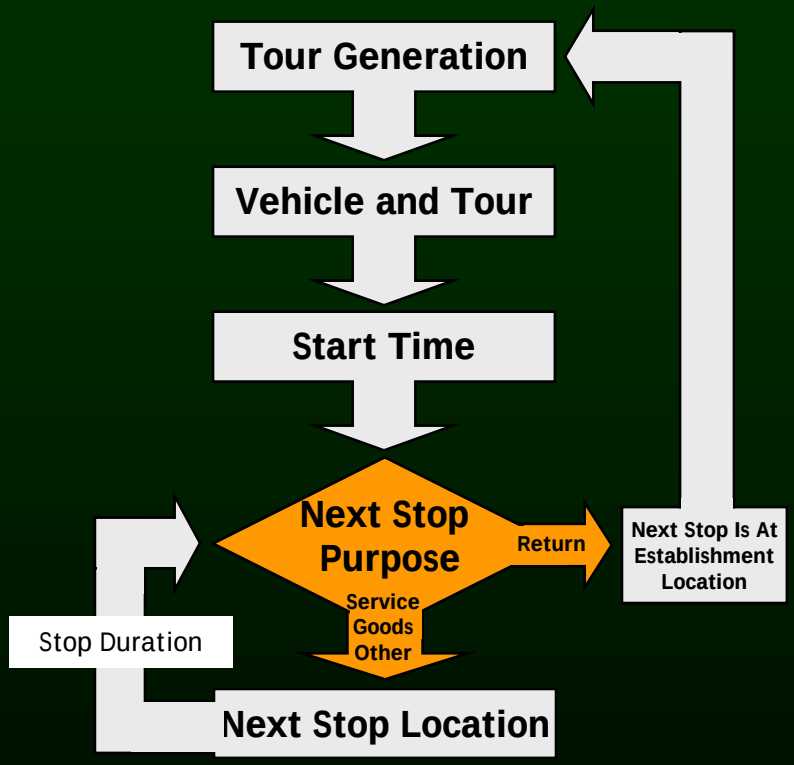
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour

Microsimulation Process



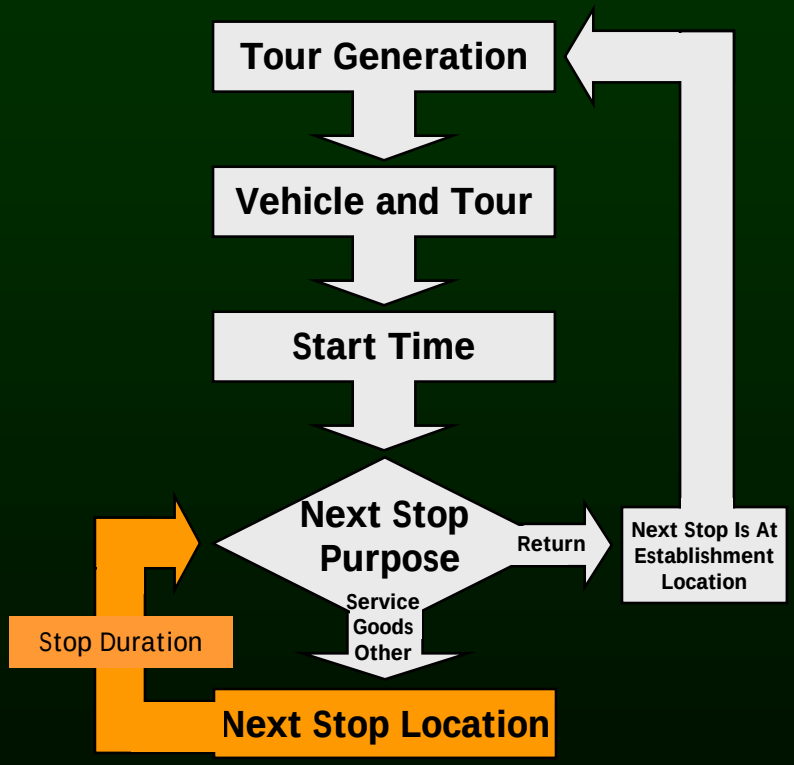
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 7:22 AM

Microsimulation Process



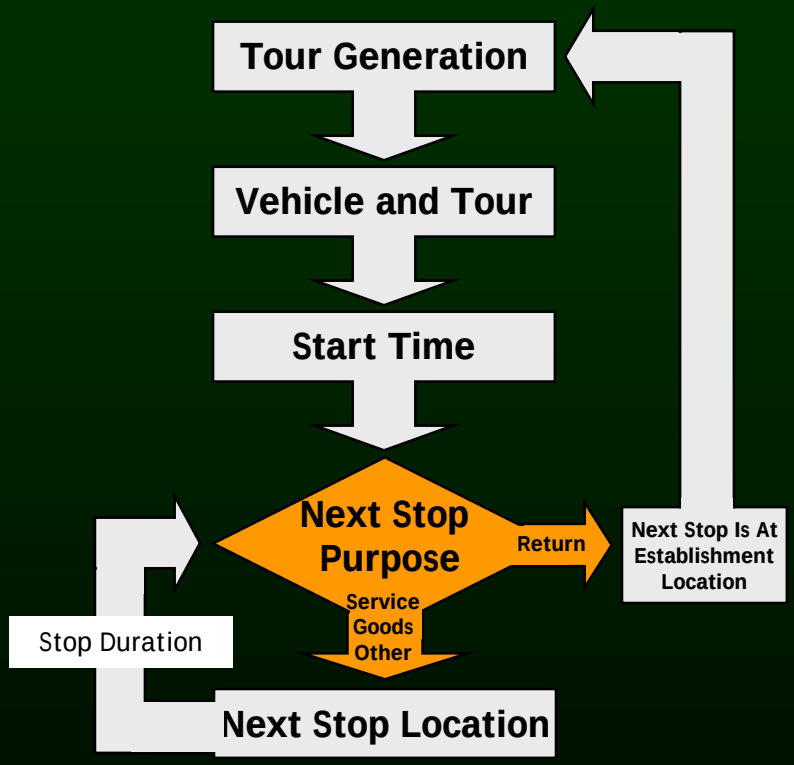
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 7:22 AM
  - Service stop

Microsimulation Process



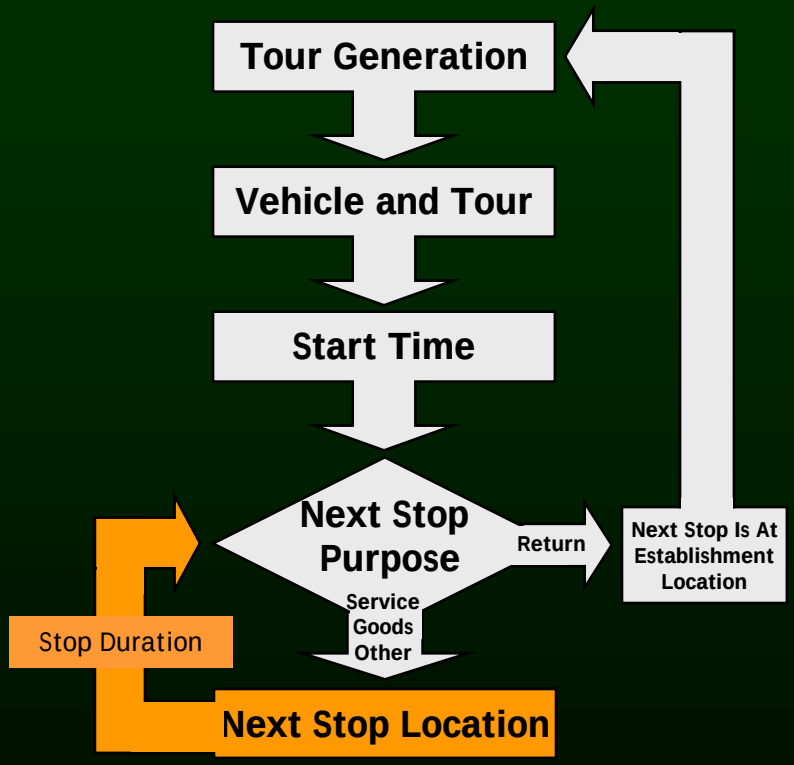
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 9:48 AM
  - Service, 211 (Stampede)

Microsimulation Process



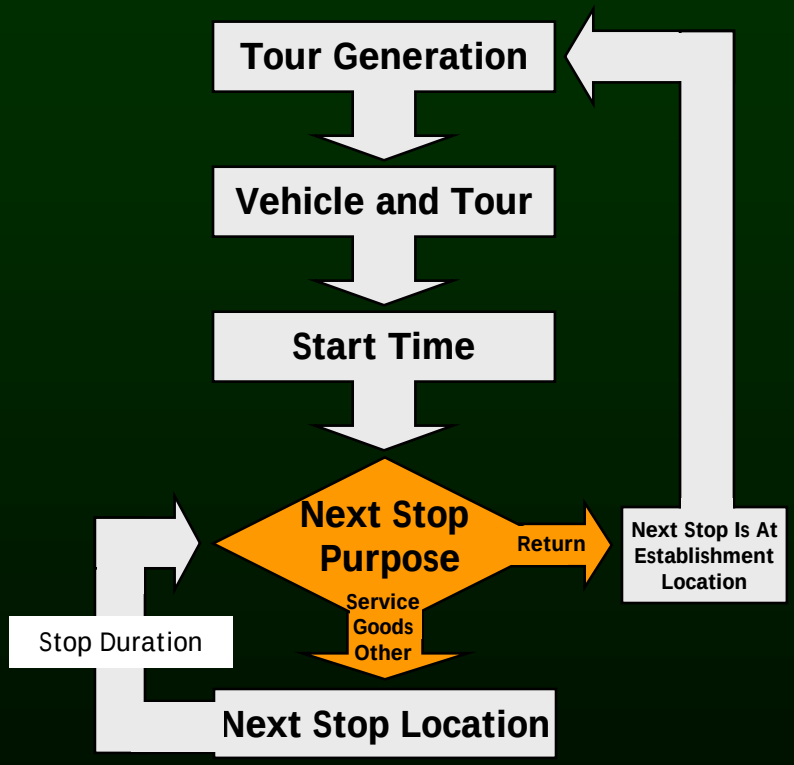
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 9:48 AM
  - Service, 211 (Stampede)
  - Service stop

Microsimulation Process



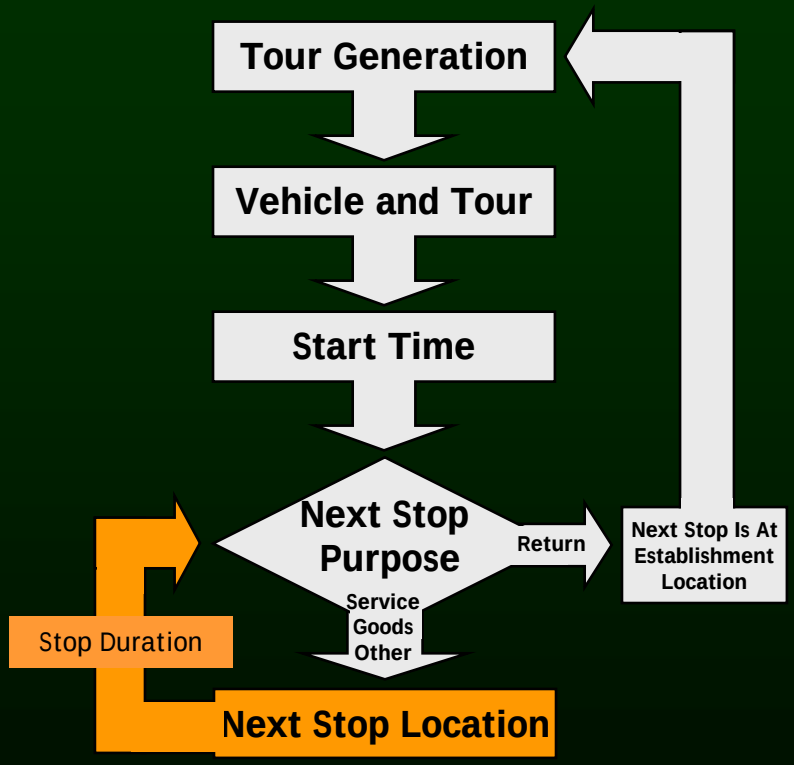
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 11:21 AM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)

Microsimulation Process



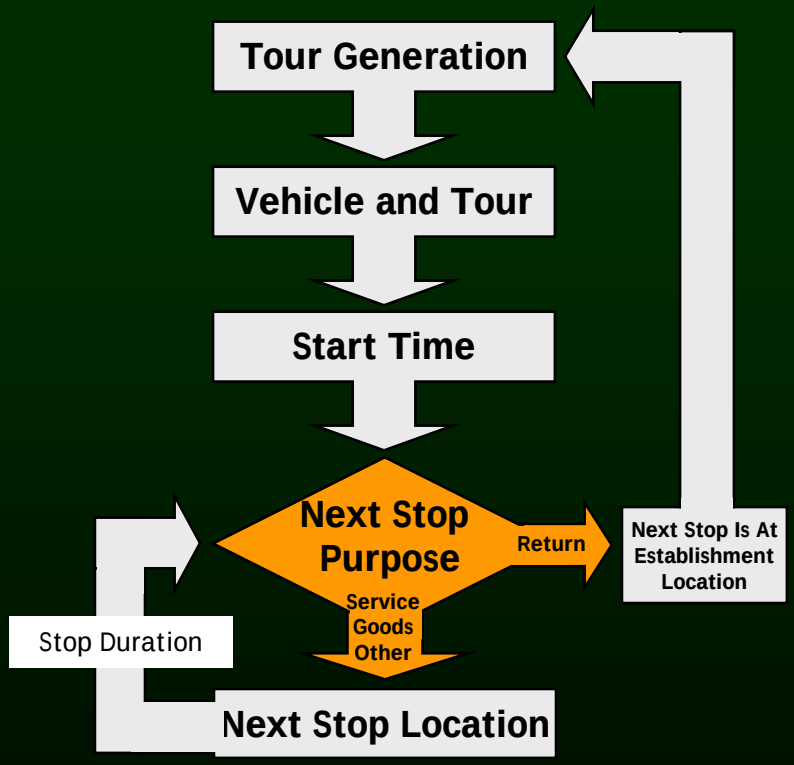
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 11:21 AM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other stop

Microsimulation Process



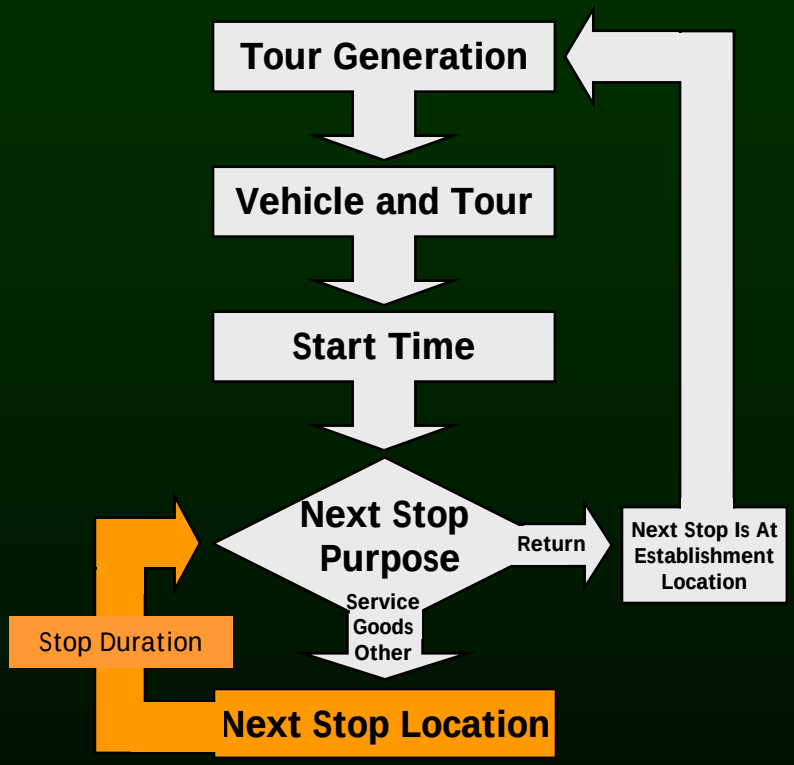
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 12:13 PM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)

Microsimulation Process



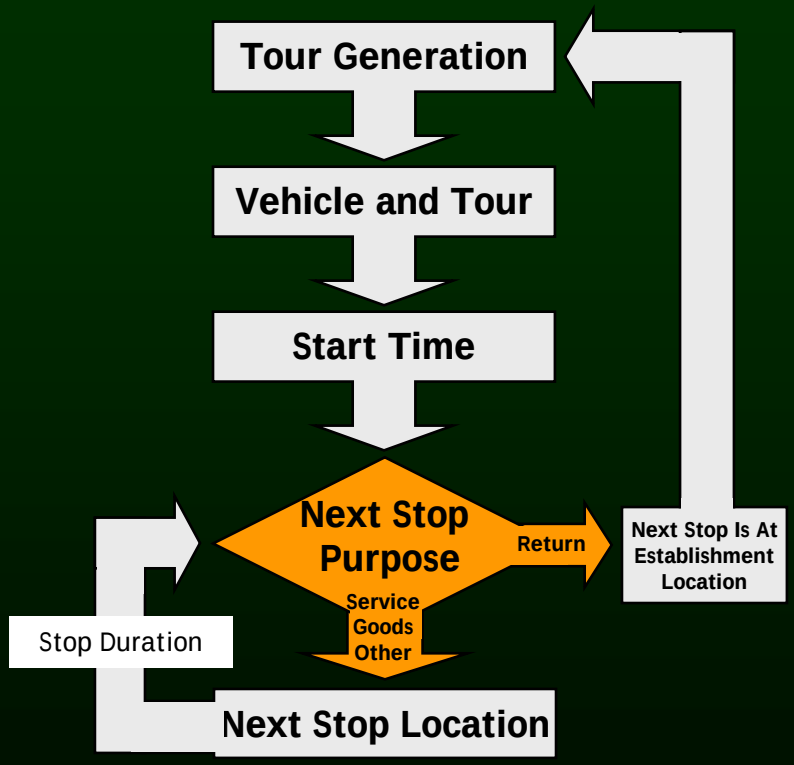
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 12:13 PM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service stop

Microsimulation Process



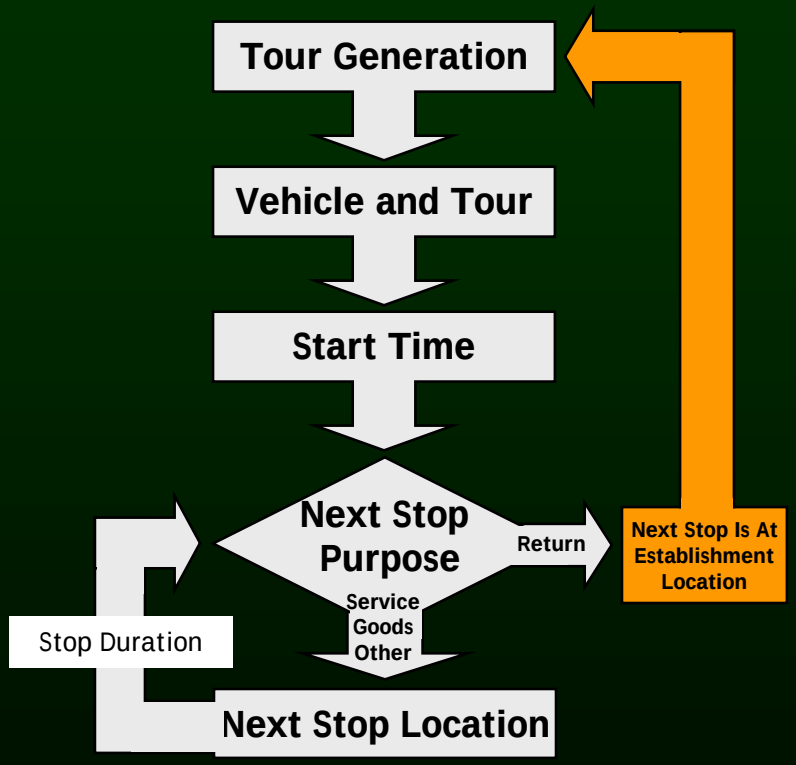
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 4:20 PM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service, 2312 (North Hill Mall)

Microsimulation Process



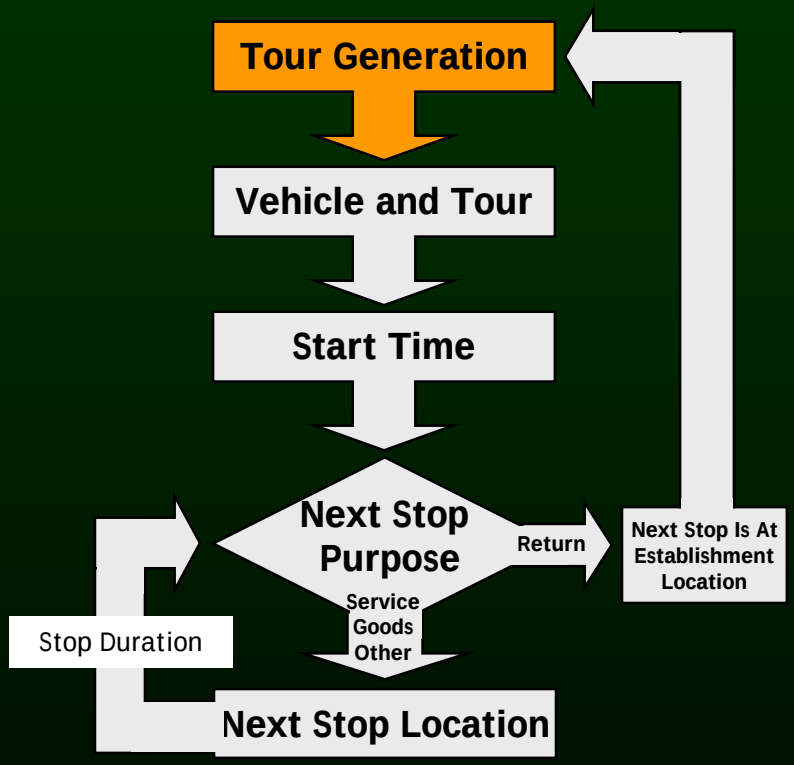
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time: 4:20 PM
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service, 2312 (North Hill Mall)
  - Return to establishment

Microsimulation Process



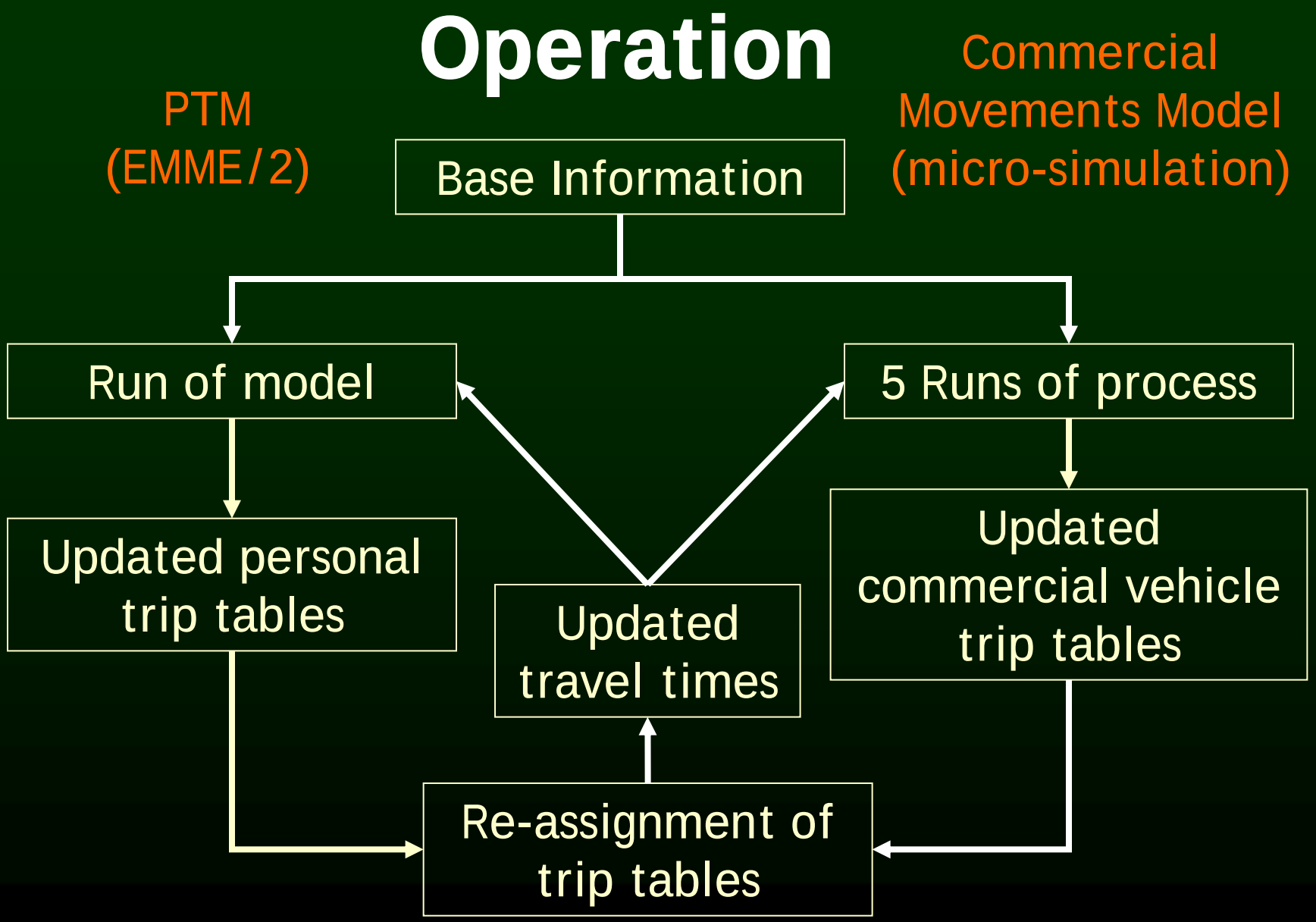
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time:
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service, 2312 (North Hill Mall)
  - Return to establishment, 340

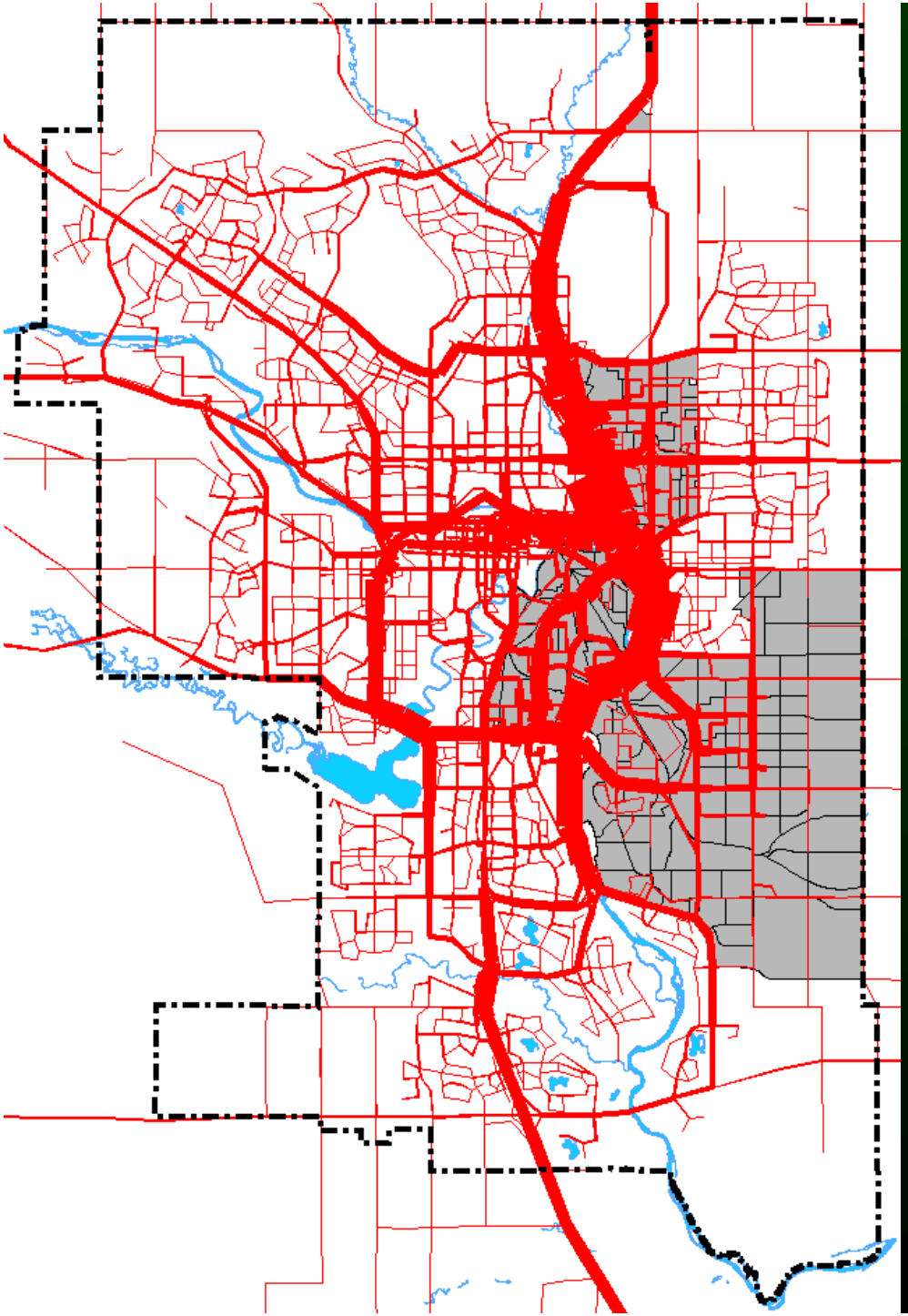
Microsimulation Process



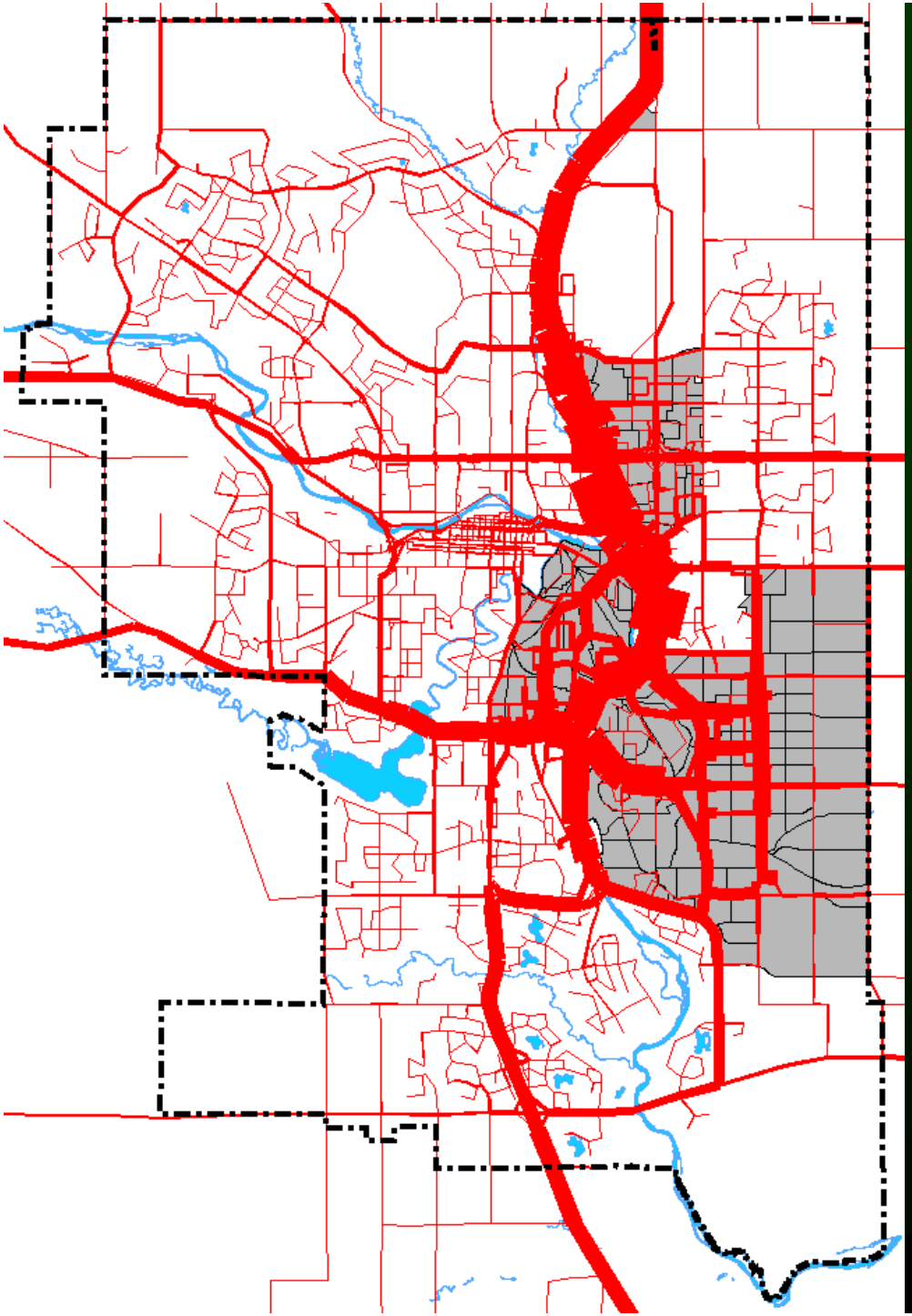
- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time:
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service, 2312 (North Hill Mall)
  - Return to establishment, 340
- Tour starting in zone 2604 (NW residential)

Operation


PTM
(EMME/2)
Commercial
Movements Model
(micro-simulation)
Base Information
Run of model
5 Runs of process
Updated personal
trip tables
Updated
travel times
Updated
commercial vehicle
trip tables
Re-assignment of
trip tables



Model network loading of light vehicle flows



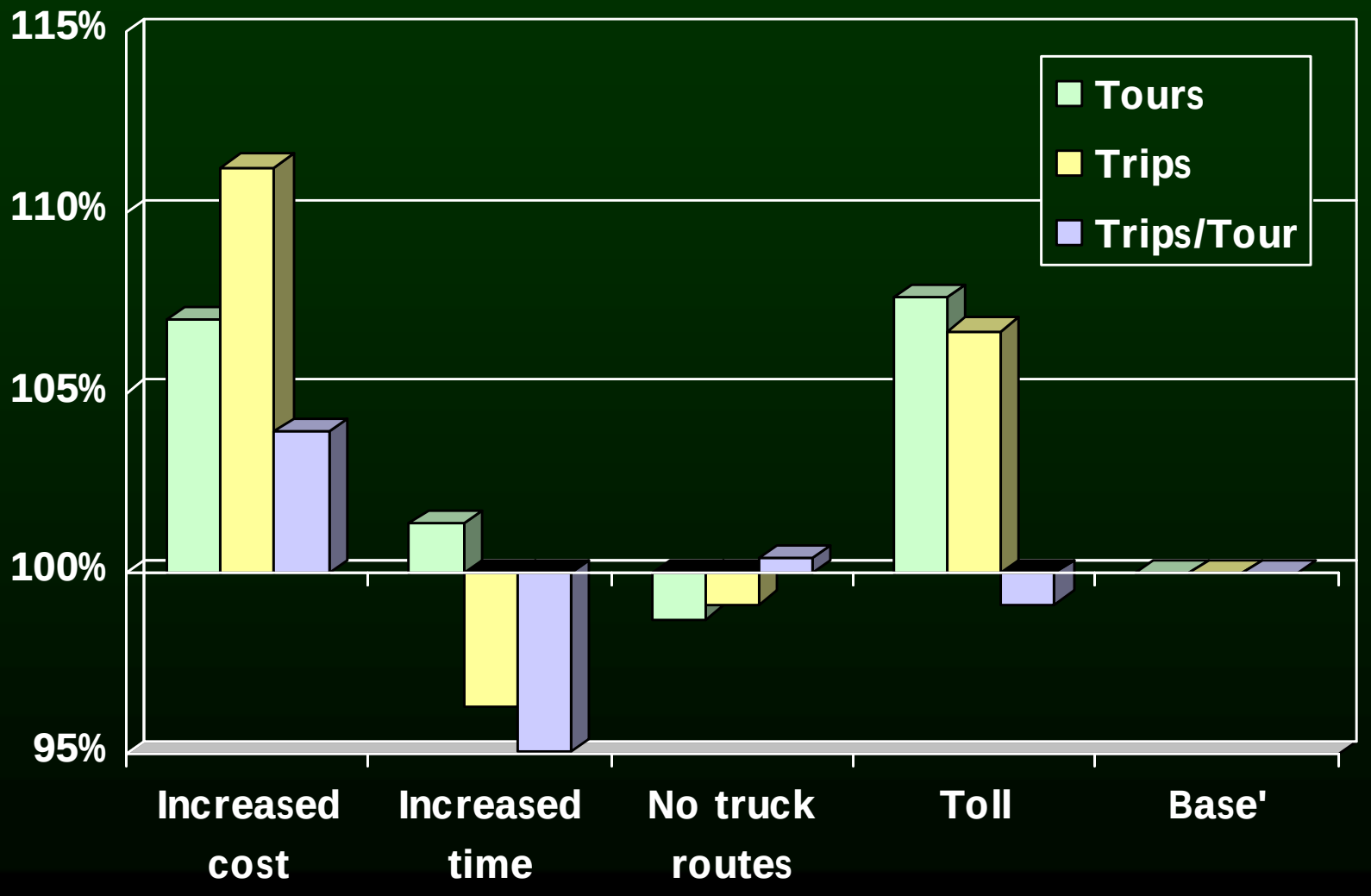
Model network loading of heavy vehicle flows

- less in CBD;
- more in industrial areas
- little on non-truck routes

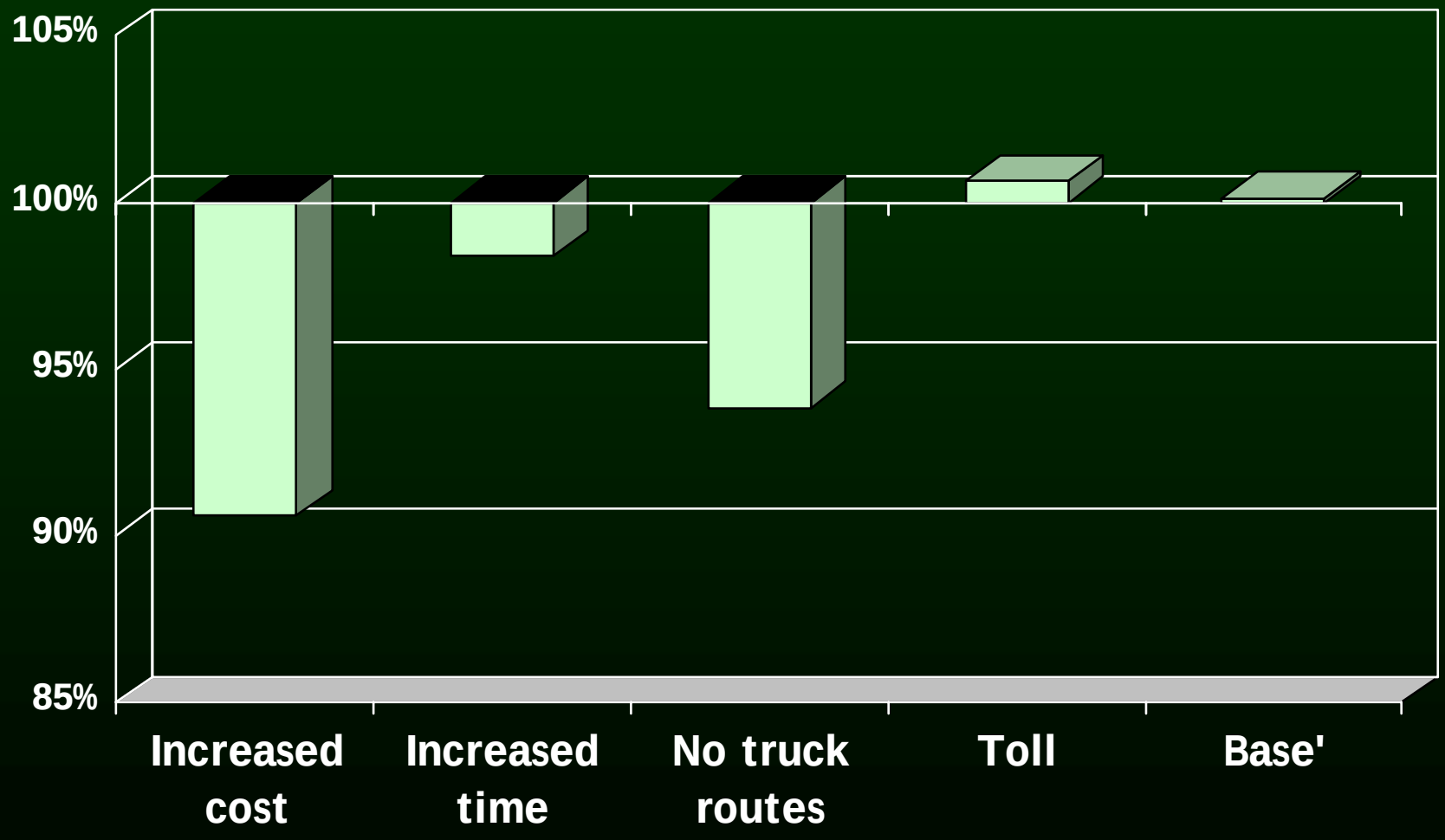
Application Results

- Being used for practical policy analysis
- A number of demonstration policy tests have produced preliminary results
- Five scenarios:
  - Base case
  - Increased cost of travel (per km)
  - Increased travel time
  - Removed truck route restrictions
  - Instituted large toll for stops in CBD

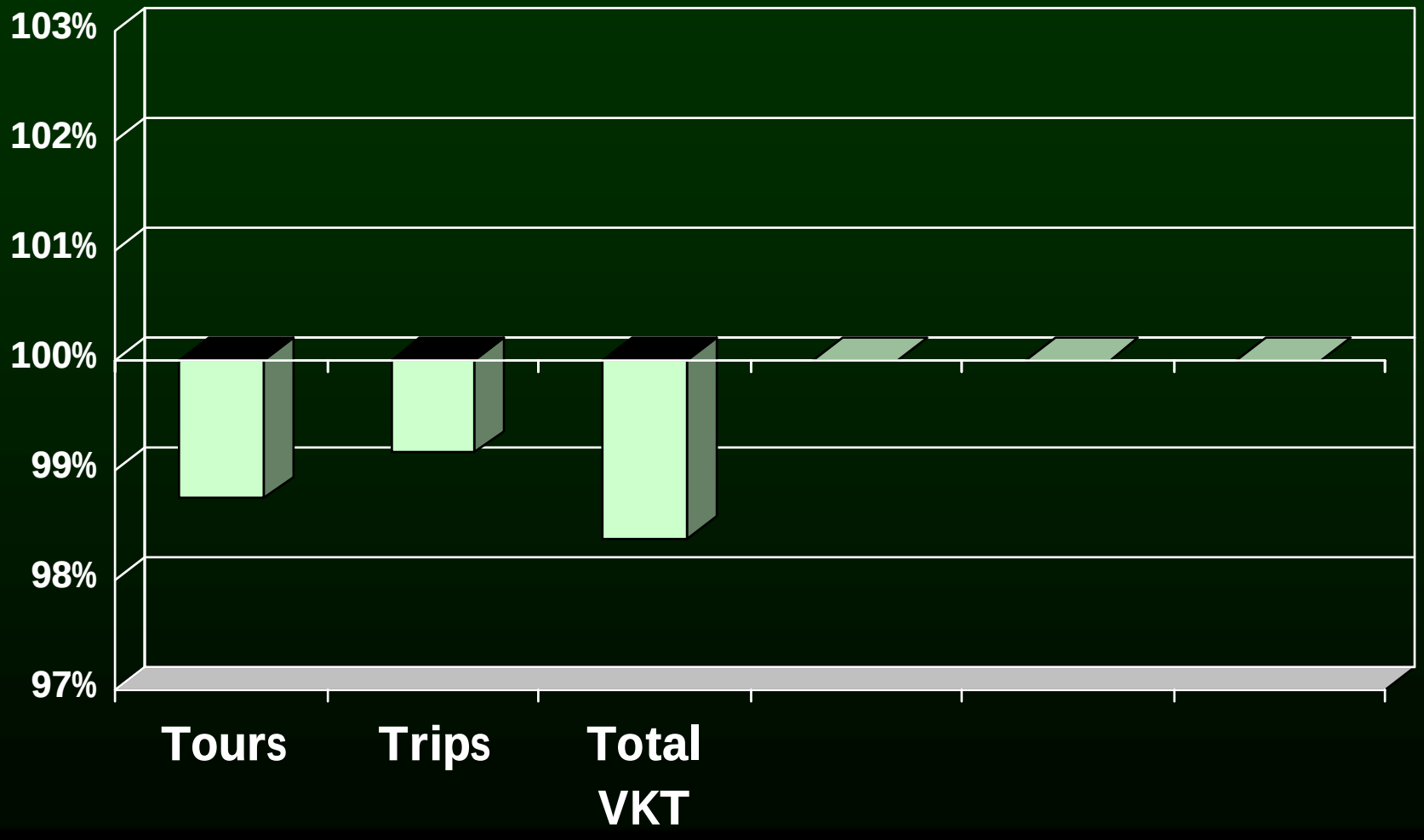
Relative to Base



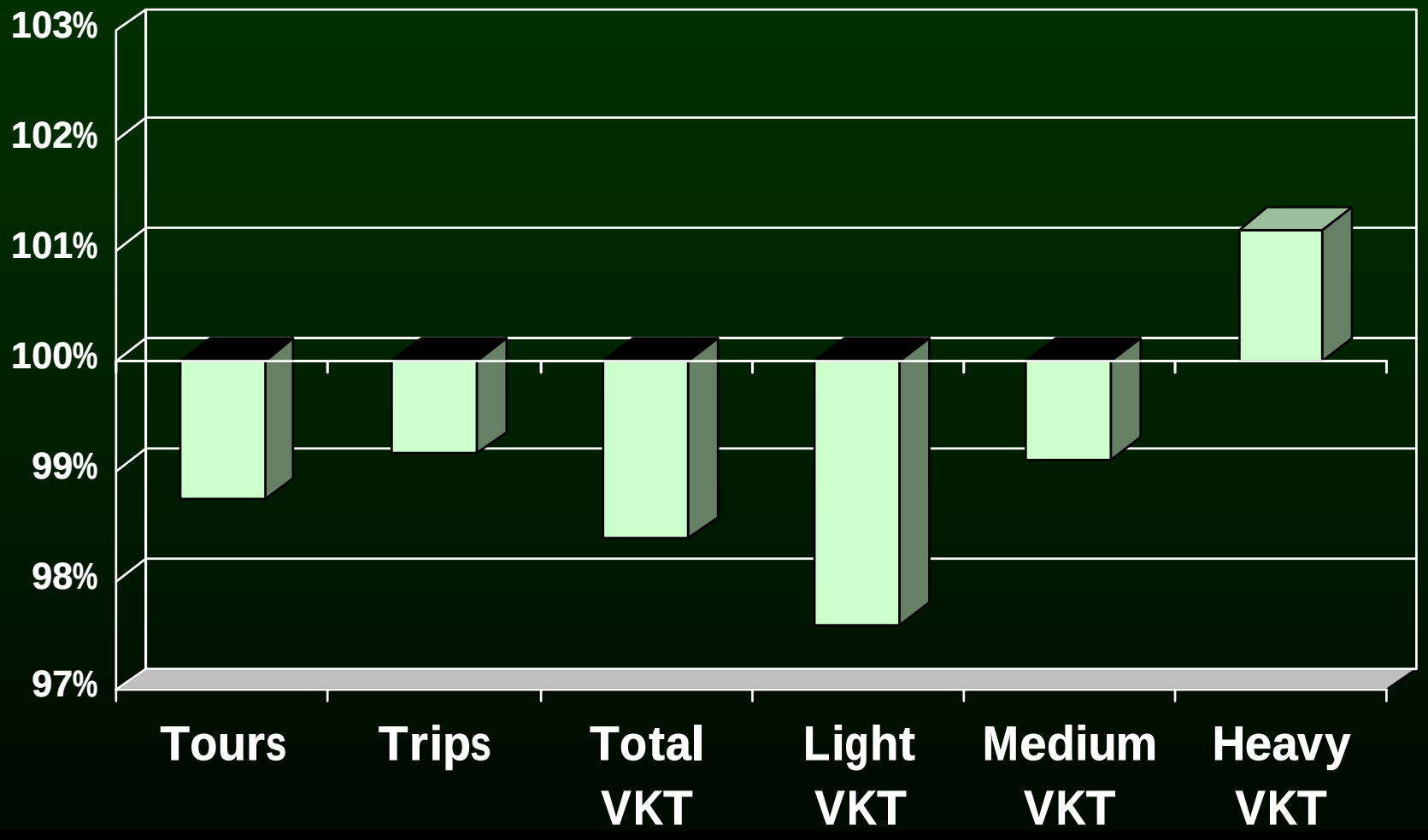
VKT Relative to Base



No Truck Routes Relative to Base



No Truck Routes Relative to Base



Conclusions

- Tour-based microsimulation approach used here
  - Successful
  - Provides direct representation of trip-chaining impacts, including empty vehicles and return trips
  - Includes service delivery
  - Well beyond ‘freight only’ and ‘large truck’ limitations
  - Useful planning tool for
    - Including commercial movements and their impacts on system
    - Assessing impacts of transportation policy and infrastructure development on commercial sectors

Conclusions

- Microsimulation stable, can integrate with aggregate, equilibrium model
- Successful tour ‘growing’ rather than ‘rubberbanding’
- Transport and Handling as a service
  - In context as part of total commercial movements
  - Helpful as consistency check
  - Double-counting issue avoided using own-account perspective

Conclusions

- Successful integration of Truck Route compliance within path choice simulation using generalized cost
- Data extremely important
  - Comparatively little known
    - urban commercial movements paid much less attention
    - few ‘rules-of-thumb’
  - Logit choice estimations provided wide range of useful insights
  - Worth substantial expense

Conclusions

- Stop duration module
  - Rudimentary sampling from observed distribution
  - ‘weak link’ in microsimulation
  - Misses influences
    - Stop order
    - Previous stop history
    - Time of day
  - More complete representation feasible, probably warranted
- Spatially disaggregated Input-Output model
  - Fit with this commercial movement model
  - Provide useful extensions into land use and economic activity

Conclusions

- Pleased with results
- Point way ahead in urban commercial movement modelling

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